Study
Report
98-01

Development of an Army Civilian Artificial Intelligence (AI) Specialty

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14. ABSTRACT *(Maximum 200 words)*:

The goal of this project was to develop the certification standards for the new specialty in Artificial Intelligence/Robotics (AI/Robotics) for Army civilians. A job analysis was conducted to identify AI-related job tasks performed by Army civilians and the knowledge areas (i.e., competencies) that are necessary to successfully perform them. Four one-on-one interviews and two workshops were used to develop comprehensive lists of AI-related job tasks and associated competencies. A job analysis survey was completed by 171 incumbents. The competency standards were developed at three workshops using the job analysis information. Competencies identified as the most important to successful job performance across different types of Army civilian jobs form the bases for the certification standards. To be certified, applicants will need to demonstrate that they have had sufficient amounts of education or experience or combinations of the two for all of the 6 "core competencies" and for three of the 18 "supplemental competencies."

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FOREWORD

In March 1995, the Deputy Assistant Secretary of the Army (Civilian Personnel and EEO Policy) and the Director of Civilian Personnel, Office of the Assistant Secretary of the Army (Manpower & Reserve Affairs) authorized work to develop an Artificial Intelligence (AI)/Robotics civilian specialty program. Under sponsorship of the Director of Information Systems for Command, Control, Communication, and Computers (DISC4), the U.S. Army Research Institute for the Behavioral and Social Sciences contracted with the Human Resources Research Organization to initiate this effort.

This project encompassed three goals: (1) identification of the population of Army civilians working in AI/Robotics; (2) identification of the competencies required to proficiently perform AI/Robotics tasks; (3) determination of training and experience required for certification (i.e., the certification standards). AI/Robotics certificants will have an additional skill identifier of AI/Robotics added to their personnel records.

The results of this effort were briefed by DISC4 to a wide variety of interested Army parties during the 2nd and 3rd quarters of FY1997.

ZITA M. SIMUTIS
Technical Director

DEVELOPMENT OF AN ARMY CIVILIAN ARTIFICIAL INTELLIGENCE (AI) SPECIALTY

EXECUTIVE SUMMARY

Research Requirement:

As the Army's proponent for artificial intelligence and robotics, the Director of Information Systems for Command, Control, Communications, and Computers (DISC4) is developing and implementing a process for awarding specialty certification to Army civilians who, regardless of career program, have demonstrated proficiency in competencies related to artificial intelligence and robotics. The purpose of this project was to (a) identify the population of Army civilians working in AI/Robotics, (b) identify the competencies required to proficiently perform AI/Robotics tasks, and (c) determine the training and experience that will be required for certification (i.e., the certification standards). Note that, for the purpose of this report, the term "AI" encompasses both AI and robotics.

Procedure:

The basic methodology of the project was to conduct a job analysis to identify AI/Robotics-related job tasks performed by Army civilians and the knowledge areas (i.e., competencies) that are necessary to successfully perform them. Competencies identified as the most important to successful job performance across different types of Army civilian jobs form the basis for the certification standards.

Four one-on-one interviews and two workshops, involving a total of 13 Subject Matter Experts (SMEs) and two officers from the Army Artificial Intelligence Center, were used to develop comprehensive lists of AI/Robotics-related job tasks and associated competencies. These lists were incorporated into a survey that was sent to all Army civilians involved in the AI/Robotics work that could be identified. Survey respondents rated the importance of each task and competency to their individual jobs.

A "data call" survey was used to help identify the population of individuals who should receive the job analysis survey. Surveys were sent to these 405 persons. Although 240 respondents returned the survey (for a response rate of 59%), a relatively large proportion of the respondents reported that AI/Robotics responsibilities accounted for none (68 people) or only 1 to 5% (50 people) of their job responsibilities. Therefore, the analyses to help identify the competencies to incorporate into the certification process were based on only the 121 individuals whose AI/Robotics responsibilities comprised at least 5% of their jobs.

Findings:

The importance ratings from the job analysis survey were used to identify competencies that are very important across a broad range of jobs (e.g., across different major commands). These were identified as core competencies. Competencies that were particularly important for respondents working in particular environments were identified as supplemental competencies. A workshop with six SMEs was held to determine the final core and supplemental competencies and decide what experience and course work would be required for certification candidates to demonstrate proficiency in the applicable areas. Their initial recommendations were compiled into a package for final review.

The task force and one additional SME made suggestions for minor changes to the certification standards. The task force met on April 7, 1997 to discuss the changes. The meeting concluded with all of the task force members agreeing to the revised certification standards.

Utilization of Findings:

To be certified, applicants will need to demonstrate that they have had sufficient amounts of education or experience or combinations of the two for each of the 6 "core competencies" and for three of the 18 "supplemental competencies."

The certification standards will be used to guide a review panel in deciding whether or not to certify individuals in the new Army civilian specialty of AI/Robotics. The AI/Robotics course database developed for this project will also aid in professional development planning for AI/Robotics professionals. The job analysis results can be used to facilitate staffing and training.

DEVELOPMENT OF AN ARMY CIVILIAN ARTIFICIAL INTELLIGENCE (AI) SPECIALTY

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INTRODUCTION

Background

This project was sponsored by the Director of Information Systems for Command, Control, Communications, and Computers (DISC4). Its purpose was to develop standards for the voluntary certification of US Army civilians working in Artificial Intelligence (AI). The certification program is intended to (a) create a coherent career path for AI/Robotics specialists and (b) fully utilize the skills, knowledges, and abilities of AI/Robotics personnel by creating a comprehensive program that focuses on the management, development, utilization, recruitment, and retention of AI/Robotics specialists.

Approval for the AI/Robotics civilian specialty program was given in October, 1994. In March, 1995, the Deputy Assistant Secretary of the Army (Civilian Personnel and EEO Policy) / Director of Civilian Personnel, Office of the Assistant Secretary of the Army (Manpower & Reserve Affairs) authorized the work required to support this effort.

AI/Robotics certificants will have an additional skill identifier of *AI/Robotics* added to their personnel records. A certificant in AI/Robotics should be able to move from one AI/Robotics position to another with little additional training in AI/Robotics.

Summary of the Project Approach

The project involved three phases: (a) identify the population of Army civilians working in AI/Robotics, (b) identify the competencies required to proficiently perform AI/Robotics tasks, and (c) determine the training and experience that will be required for certification (i.e., the certification standards). The second phase was accomplished via a job analysis. The job analysis information was obtained primarily via meetings with groups of AI/Robotics Army civilians and a job analysis survey sent to the entire known population of AI/Robotics Army civilians.

The determination of the certification standards was the last step in the following sequence:

- set up a task force
- obtain information about tasks and competencies via 1995 Informal Survey
- interview incumbents to refine lists of tasks and competencies
- conduct workshops to refine lists of tasks and competencies
- locate job analysis survey population via 1996 Data Call
- develop and distribute job analysis survey
- analyze survey responses to determine important tasks and competencies
- conduct workshops to determine certification standards

These components of the project are briefly described below.

Set up Task Force

A task force of four Army civilians working in AI/Robotics was set up by the sponsor to help plan and execute the project. Several task force meetings were held during the project. In addition, the task force members reviewed materials and participated in workshops. The characteristics of the task force members are shown in Table 1.

1995 Informal Survey

The 1995 Informal Survey was distributed by the Army to obtain information about AI/Robotics jobs that would be helpful in creating the initial lists of tasks and competencies. The information contained answers to some open-ended questions about the respondents' positions, job descriptions, vita curriculae, and descriptions of some AI/Robotics projects. The data call results also identified some of the career programs, commands, and subcommands that had AI/Robotics positions.

From this information, the following items were developed:

- a preliminary task list
- a preliminary competency list
- a list of degree programs of people in AI/Robotics
- a list of institutions that offer training in AI/Robotics
- demographic information about the respondents

SME Interviews

All four task force members were interviewed one-on-one to further develop the task and competency lists. In each interview, the SME first examined the current lists of tasks and competencies and suggested additions, deletions, and modifications. The SMEs were also asked to make additions to the lists of AI/Robotics training institutions and degree programs of people in AI/Robotics.

Job Analysis Workshops

Project staff facilitated two one-day job analysis workshops which used a group consensus format. The participants were incumbents in AI/Robotics. After a brief orientation, the group made additions, deletions, and modifications to the list of tasks. Then the appropriateness of the task categories was discussed. The group also made additions, deletions, and modifications to the list of competencies. Then the appropriateness of the competency categories was discussed. Finally, the list of AI/Robotics training providers was edited for completeness and accuracy.

The first workshop was held January 25, 1996. Five civilians (and one officer) in AI/Robotics attended. The second workshop was held February 21, 1996. Eight civilians (and one officer) in AI/Robotics attended. In addition to the activities described in the paragraph above, the participants at the second workshop also discussed the proposed rating scales for the job analysis survey. As a result of this discussion, the proposed *breadth of knowledge required* and *depth of* *knowledge required* scales were replaced with *importance* and *level of knowledge required* scales because the breadth and depth scales were thought to be confounded.

Table 1. Characteristics of the Task Force Members

SME Characteristic	
	First Task Force Member
Job Title	Operations Research Analyst
Grade Level	GS-13
Number of People Supervised	0
Years in Current Position	11
Years of Experience in AI	7
Current Location	U.S. Army Concepts Analysis Agency
Gender	Female
	Second Task Force Member
Job Title	Electronics Engineer / Team Leader
Grade Level	GS-13
Number of People Supervised	9
Years in Current Position	1
Years of Experience in AI	9
Current Location	Aberdeen Test Center, Aberdeen Proving Ground
Gender	Male
	Third Task Force Member
Job Title	Operations Research Analyst
Grade Level	GS-13
Number of People Supervised	0
Years in Current Position	8
Years of Experience in AI	6
Current Location	U.S. Army Logistics Integration Agency, New Cumberland
Gender	Female
	Fourth Task Force Member
Job Title	Supervisory Materials Engineer
Grade Level	GS-13
Number of People Supervised	14
Years in Current Position	5
Years of Experience in AI	3
Current Location	U.S. Army Research Lab, Aberdeen Proving Grounds
Gender	Male

1996 Data Call

The 1996 data call was performed to obtain an exhaustive list of Army civilians working in AI/Robotics. This list would be used as the distribution list for the job analysis survey.

The information from this data call was used to create a database of civilians working in AI/Robotics. The database contained the following information about each respondent:

- Name
- Address
- Major Command
- Major Subordinate Command
- Agency/Activity
- Mailing Address
- Career Program
- Grade
- Job Series
- Percent of job devoted to AI/Robotics activities

Job Analysis Questionnaire

The job analysis questionnaire had four sections: general instructions, questions about the respondent's position and training, a task ratings section, and a competency ratings section. In the task ratings section, respondents rated the *importance* of 37 tasks and both the importance of and level of knowledge required for 51 competencies.

A draft of the job analysis survey was sent to sponsor representatives and to the participants in the second workshop for review. A few minor changes were made based on the reviewers' suggestions.

The survey materials were mailed directly to each person on the list (developed from Data Call 2) of Army civilians working in AI/Robotics. The materials consisted of the job analysis questionnaire, a cover letter, and a stamped return envelope.

Of the 405 surveys that were mailed, 240 were returned. This represents a response rate of 59%. Only 171 respondents, however, performed any AI/Robotics in their jobs. Of these, 121 spent more than 5% of their time on AI/Robotics activities.

Analysis of Survey Results

Based on the responses of the survey respondents who spent at least 5% of their time performing AI/Robotics tasks, the critical AI/Robotics tasks and the important competencies were determined. These tasks and KSAs were reviewed at a meeting of the task force. The competencies *simulation* and *modeling* were deleted because the task force members agreed that, although these two competencies are often used in conjunction with AI/Robotics competencies, they themselves were not AI/Robotics competencies.

Certification Standards

The task force met on October 22, 1996, to finalize the list of competencies and begin the development of the certification standards. This workshop identified the courses and training that could be used to fulfill the requirements for each competency. One of the task force members had developed a list of many of the available courses in AI/Robotics. The workshop participants determined which courses could be used to fulfill the requirements for each competency.

The task force and three other AI/Robotics incumbents met January 21–22, 1997. The course requirements developed at the previous meeting were reviewed. A working draft of the experience standards was also developed at this meeting. After the meeting, this draft was mailed to the workshop participants for review.

After the participants' suggested changes were incorporated into the draft of the experience standards, definitions for each of the competencies were developed. All the draft certification materials were then sent to the task force members for review. HumRRO then modified the materials based on the suggestions by task force members.

The task force met a final time, on April 7, 1997, to review and finalize the certification. standards. At this meeting, one of the core competencies, *search strategies*, was moved down to the level of a supplemental competency. Minor changes were made to other portions of the certification standards. At the end of the meeting, all the task force members concurred with the revised certification standards.

Overview of the Report

The remainder of this report discusses, in detail, the outcomes at each step of the project.

Identification of Population and Positions. The results of two data calls are described here. The data calls obtained information about the civilians working in AI/Robotics in the Army. Frequency analyses for several position-related variables, such as job series, are provided.

Development of Lists of Tasks and Competencies. This section describes, in detail, how the lists of tasks and competencies for the job analysis survey were developed. This process included a data call, interviews with incumbents, two workshops with incumbents, and a final review by the task force members.

Job Analysis Survey. This section describes both the survey administration process and the results of the survey. The results of several analyses of the competency and task ratings are presented. The rationale for determining which competencies are important and which tasks are critical is also explained.

Construction of the Course Information Base. This section describes the development of the database of AI/Robotics courses that can be used to meet certification requirements.

Establishment of the Task-Competency Linkages. This section describes the procedure for linking the critical tasks with the important competencies. The results of the linking survey are presented.

Competency Standards Recommendations. This section presents the recommended certification standards and describes the final steps in determining these standards. The report concludes with suggestions for implementing the certification program.

IDENTIFICATION OF POPULATION AND POSITIONS

The results of two data calls are described here. The data calls obtained information about the civilians working in AI/Robotics in the Army. Frequency analyses for several position-related variables, such as job series, are provided.

1995 Informal Survey

In May, 1995, the project's sponsor completed an informal survey of civilians working in AI/Robotics. A questionnaire was distributed to a small sample to provide initial information about Army civilian jobs that involved AI/Robotics. This information was used to (a) develop an initial list of tasks, competencies, training sources, and formal education and (b) help create a distribution list for a comprehensive data call which would attempt to identify all Army civilians working in AI/Robotics.

The survey was sent to 61 agency points of contact (POCs). Individuals returned 52 completed surveys; 41 sites indicated that they had no civilians working in AI/Robotics. The survey results show that (a) most of the respondents were in Career Program 16 (Non-Construction Engineers & Scientists), (b) the largest percentage of respondents (44%) were in pay grade GS-13, and (c) for half of the respondents, more than 70% of their duties were related to AI/Robotics (see Tables 2–4).

Table 2. 1995 Informal Survey: Percentage of Respondents per Career Program

Percentage of Respondents	Career Program	
81	16	Engineers & Scientists (Non-Construction)
9	34	Information Mission Area
6	18	Engineers & Scientists (Construction)
2	11	Comptroller
2	14	Contracting & Acquisition

Note. Percentages are based on a total of 50 responses.

Table 3. 1995 Informal Survey: Percentage of Respondents per Grade Level

Percentage of Respondents	Grade Level
4	GS-11
28	GS-12
44	GS-13
20	GS-14
4	GS-15

Note. Percentages are based on a total of 50 responses.

Table 4. 1995 Informal Survey: Percentage of Duties that are AI/Robotics-Related

Percentage of Respondents	Percentage of Duties that are AI/Robitics-Related
23	100
17	80-99
17	60-79
13	40-59
15	20-39
15	1-19

Note. Percentages are based on a total of 47 responses.

Many of the respondents provided job descriptions, curriculae vita, information about some of their projects, sources of training and education, formal degrees, or lists of AI/Robotics-related courses. This information was used later to develop preliminary lists of tasks, competencies, and relevant courses.

1996 Data Call

In December, 1995, a data call was issued as part of the present project to help develop a comprehensive list of civilians in AI/Robotics. Initially, sets of questionnaires were sent to the POCs at all Major Army Commands. In addition, POCs were identified at the following subordinate commands within the HQDA Major Army Command: HQ staff and principals, National Guard Bureau, and the functional chief at each of the career programs identified by the 1995 informal survey.

When the initial distribution of the questionnaires failed to produce the anticipated volume of responses, alternative modes of distribution were used. About two weeks past the deadline for the return of the completed surveys, each POC was phoned; phone calls were made up the chain of command until an adequate response was achieved. In some cases, the final POC was the commanding general. The inadequate initial response can be at least partially attributed to a misunderstanding by some POCS: They distributed the questionnaires only to the command's primary activity rather than to all subordinate activities as requested by the cover letter. The difficulty in identifying the appropriate POC for some activities also hindered the efficient distribution of the questionnaires. The data call was completed in May, 1996.

The questionnaire identified 405 civilians who perform some tasks related to AI/Robotics. Seven Career Programs and 24 Job Series were represented. For reasons discussed in the following section, the results from the data call are probably not accurate. There are probably far fewer than 405 civilians performing true AI/Robotics tasks, and the headcounts in Figure 1 and Tables 5-8 are probably substantial overestimates.

About one quarter of the respondents (99 people) spent at least half of their time doing AI/Robotics work; for another 43% (177 people), AI/Robotics was less than six percent of their job. Figure 1 shows a detailed histogram. The shape of this distribution was similar across Job Series, Career Programs, and Grade Levels. The one exception was that people in grade levels GS-14 and GS-15 tended to spend less time in AI/Robotics activities than people in lower grade levels.

Tables 5-8 and Figure 1 show respondent frequencies by Career Program, Job Series, and Grade Level. The greatest number of respondents were in Career Program 16 - Engineers and Scientists (non-construction); it accounted for 85% of the respondents. The most common Job Series was 855 - Electronics Engineering. Finally, most (61%) of the respondents were in grades GS-12 and GS-13.

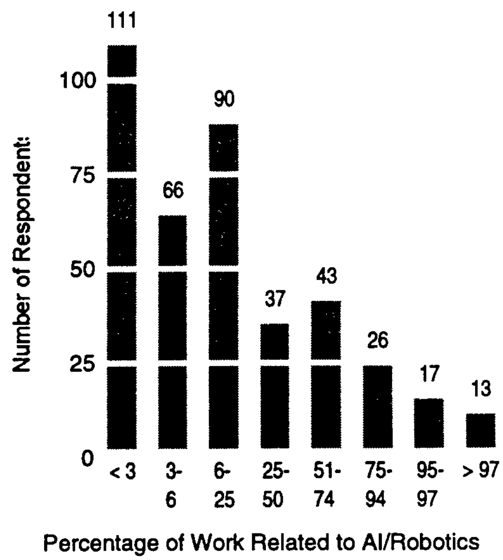


Figure 1. 1996 data call: Histogram of percentage of work related to AI/Robotics.

The information from this data call was used to create a database of civilians working in AI/Robotics. The database contained the following information about each respondent:

- Name
- Address
- Major Command
- Major Subordinate Command
- Agency/Activity
- Mailing Address
- Career Program
- Grade
- Job Series
- Percent of job devoted to AI/Robotics activities

Table 5. 1996 Data Call: Frequencies for Career Program

Number of Respondents	Career Program	
319	16	Engineers & Scientists (Non-Construction)
33	34	Information Mission Area
8	18	Engineers & Scientists (Construction)
7	11	Comptroller
5	00	none
3	13	Supply Management
1	24	Transportation Management
1	26	Contracting & Acquisition

Table 6. 1996 Data Call: Frequencies for Grade Level

Number of Respondents	Grade Level
1	GS-05
1	GS-07
4	GS-09
32	GS-11
113	GS-12
134	GS-13
58	GS-14
39	GS-15
2	GM-13
6	GM-14
6	GM-15
1	SES
1	ST

Table 7. 1996 Data Call: Frequencies for Major Command

Number of Respondents	Major Command
339	AMC
30	HQDA
13	TRADOC
9	Corps of Engineers
4	MEDCOM
8	Others

Table 8. 1996 Data Call: Frequencies for Job Series

Number of Respondents	Job Series	
80	855	Electronics Engineering
50	1515	Operations Research
40	801	General Engineering
37	180	Psychology
34	830	Mechanical Engineering
32	334	Computer Specialist
27	861	Aerospace Engineering
21	301	Information Systems Manager
14	806	Materials Engineering
14	1550	Computer Science
13	1310	Physics
12	1520	Mathematics
8	850	Electrical Engineering
7	403	Microbiology
7	896	Industrial Engineering
3	854	Computer Engineering
2	1529	Mathematical Statistics
1	856	Electronics Technician
1	858	Biomedical Engineering
1	893	Chemical Engineering
1	1320	Metallurgy
1	1321	Chemistry
1	2101	Transportation Specialist
1	2130	Traffic Management

Job Analysis Survey

A job analysis survey was mailed to all 405 data call respondents. (This survey will be discussed at length later.) Although all of the data call respondents indicated that their jobs involved at least some activities related to AI/Robotics, 29% of the 240 job analysis survey respondents indicated that they performed no work in AI/Robotics. It is also reasonable to assume that many of those who failed to respond to the job analysis survey also did not perform AI/Robotics tasks.

There are at least three possible explanations for this discrepancy. First, it is known that several data call questionnaires were filled out for incumbents by other people. Some of these incumbents may not have done any work in AI/Robotics (the people who completed their questionnaires mistakenly thought that they did).

Second, it is possible that many of the people who were willing to answer a few questions on the two-page data call did not want to spend the time to complete the much longer job analysis survey. The survey was 16 pages long and contained 152 questions. Therefore, some of these people may have stated that they did no work in AI/Robotics to avoid answering the survey.

Third, it seems likely that some people may have discovered that they did not perform any of the tasks listed in the survey and concluded that they do not work in AI/Robotics after all. That is, their definition of AI/Robotics was narrower for the job analysis survey than for the data call. There is evidence that this occurred. First, in the data call, AI/Robotics activities accounted for less than three percent of the job for 27% of the respondents and less than six percent of the job for 43% of them. Then, in some of the returned job analysis surveys, the respondent had rated only the first few tasks (and rated each of them as not being performed) and had also filled in the circle at the top of the questionnaire to indicate that they were *NOT an Army civilian working in artificial intelligence or robotics*. It is likely that these people (a) started filling out the survey, (b) realized that they performed none of the AI/Robotics tasks, (c) concluded that they did not do any AI/Robotics activities after all, and (d) filled in the circle at the top of the questionnaire to indicate that they did not work in AI/Robotics.

Thus, although the data call identified 405 Army civilians performing AI/Robotics work, this figure appears to be a substantial overestimate of the actual population. The job analysis survey identified a much lower figure of 170 people working in AI/Robotics, and even this number might be judged to be an overestimate if you consider that it includes people who spend minimal time on AI/Robotics activities. Analyses for the job analysis survey used only the 120 (71%) respondents who indicated that they spend 5% or more of their time on AI/Robotics tasks. Thus, the population actually contains a minimum of 120 positions if this narrower definition is used (i.e., spend 5% or more of the time on AI/Robotics tasks) and a minimum of 240 positions if the wider definition is used (i.e., spend *any* time on AI/Robotics activities). A full description of the sample we used for analysis purposes is provided later in this report.

DEVELOPMENT OF TASK AND COMPETENCY LISTS

The lists of tasks and competencies were systematically developed via the following sequence:

- obtain information about tasks and competencies via 1995 Informal Survey
- interview incumbents to refine lists of tasks and competencies
- conduct workshops to refine lists of tasks and competencies

Construction of Preliminary Lists

As discussed previously, the 1995 informal survey of civilians working in AI/Robotics provided information about the jobs of 52 people working in AI/Robotics. A list of tasks and competencies was developed based on job descriptions, curricula vitae, and descriptions of projects provided by the survey respondents.

Individual job analysis interviews were held with the four project task force members. All were civilians working in AI/Robotics and had several years experience in AI/Robotics. The characteristics of these four SMEs were shown previously in Table 1. The first interview used the lists of tasks and competencies developed from the 1995 informal survey as a starting point. The lists were modified during each interview. These updated lists were then used to begin each subsequent interview. A structured interview protocol was used to conduct these interviews.

Each interview consisted of the following steps:

- Explain the format and purpose of the interview.
- Explain the proper format of task and competency statements.
- Review the current lists of tasks and competencies. Add, modify, and delete task and competency statements.
- Ask relevant questions from the list of job analysis interview questions. Use the answers to modify and add task and competency statements.
- Review the lists of training sources and relevant educational programs. Add, modify and delete items in these lists.

After the last interview, the preliminary lists of tasks and competencies were completed. These lists would be used in the first job analysis workshop.

Job Analysis Workshops

Two job analysis workshops were conducted to develop the lists of tasks and competencies. The two workshops, held on January 24–25 and February 22–23, 1996, each lasted 1½ days. There were five SMEs at the first workshop and eight SMEs at the second. In addition, an officer from the Army Artificial Intelligence Center attended both workshops. Each task force member attended one workshop. The workshop participants were chosen by the sponsor to represent a variety of AI/Robotics positions. The characteristics of the participants are shown below in Table 9. There were 11 white males, two white females, and one African American male at the workshops.

The workshops were conducted by the project staff. Each workshop began with an overview of the entire project followed by a synopsis of the workshop. Next, the SMEs were instructed on how to write task and competency statements. The remainder of the time was devoted to developing the lists of tasks and competencies. After the SMEs read the task list to themselves, they gave suggestions for deleting, adding, or modifying task statements. The revised list was reviewed and further refinements were made. The same procedure was followed for the competencies as well. The workshop participants also reviewed the task and competency rating scales proposed for the job analysis survey.

The lists of tasks and competencies developed via the interviews were used as the starting point in the first workshop. Similarly, the lists revised during the first workshop were used as the starting point for the second workshop. Throughout the workshops, managerial tasks that required no knowledge of AI/Robotics were excluded from consideration.

JOB ANALYSIS SURVEY: DESCRIPTION OF THE SAMPLE AND ADMINISTRATION PROCEDURES

After the second job analysis workshop, a draft of the job analysis questionnaire was developed. The draft contained instructions, biographical questions, and the lists of tasks and competencies. The draft was sent to the task force members for review. Minor changes were made based on the reviewers' comments.

Job Analysis Questionnaire

The job analysis questionnaire (see Appendix C) had four sections: general instructions, questions about the respondent's position and training, a task ratings section, and a competency ratings section. In the task ratings section, respondents rated the *importance* of 37 tasks and both the importance of and level of knowledge required for 51 competencies. The questionnaire contained the following sections:

- General Instructions
- Background questions
- Task rating section. Each of the 37 tasks was rated on how much it was a part of the job compared with the other AI/Robotics tasks performed by the respondent.
- Knowledges (i.e., competencies) ratings section. Each of the 51 knowledges was rated on two things: (a) its importance relative to other AI/Robotics knowledges and (b) the level of knowledge required for successful performance.
- Related training section. Respondents were instructed to list names and sources of the AI/Robotics courses they had taken.

Administration Procedures

The questionnaire was mailed on June 17, 1996, directly to the 405 people identified by the data call as civilians working in AI/Robotics (and for whom we had addresses: five of the 405 data call respondents omitted their address). Included with the questionnaire was a cover letter from the Office of the DISC4 signed by the Director. The cover letter instructed that the questionnaire be mailed directly to HumRRO by July 10, 1996 (i.e., about four weeks later). Even if the person receiving the questionnaire did not perform any AI/Robotics activities, the instructions were to return the uncompleted questionnaire with their name on it. Although the respondents put their names on the questionnaires, they were assured that their results would be kept confidential and not used to evaluate them in any way. One week before the deadline, a

Table 9. Characteristics of the Job Analysis Workshop Participants

Job Series	Grade	Years in Current Position	Years Experience in AI	Location
806 - Materials Engineering	13	5	3	AMC, Army Research Lab, Aberdeen Proving Ground
?	?	?	?	Security Asst. Command
?	?	?	?	AMC, Army Research Lab, Aberdeen Proving Ground
1530 - Statistician	13	2	12	AMC, Army Research Lab, Aberdeen Proving Ground
1520 - Mathematics	13	2	12	AMC, Army Research Lab, Aberdeen Proving Ground
830- Mechanical Engineering	12	4	5	MTMC, Transportation Engineering Agency
?	?	?	?	Army Research Lab, Adelphi
830- Mechanical Engineering	11		5	USAFISA, Ft. Belvoir
334 - Computer Specialist	11	5	8	IS Command, Army Re-use Center
806 - Materials Engineering	14	4	3	IS Command, Army Re-use Center
801 - General Engineering	14	?	?	AMC, TECOM, Aberdeen Proving Ground
855 - Electronics Engineering	13	1	9	AMC, Aberdeen Test Center, Aberdeen Proving Ground
1515 - Operations Research	13	11	7	HQDA, Chief of Staff, Army Concepts Analysis Agency

reminder postcard was mailed to those who had not yet returned the questionnaire. The postcard instructed that the questionnaire be returned as soon as possible, even if that meant going past the deadline.

Description of the Sample

Of the 405 surveys that were mailed, 240 were returned. This represents a respectable response rate of 59%. Table 10 shows the details concerning the survey response rate. These statistics are complicated by the large number of respondents who stated that they did no work in AI/Robotics. This issue was discussed in detail in the *Identification of Population and Positions* section above.

Table 10. Job Analyses Survey Response Rates

	Number	Percent of Number Mailed
Mailed	405	100
Returned questionnaire on time	240	59
Returned questionnaire, AI/Robotics work is at least some part of job	171	42
Returned questionnaire, AI/Robotics work is > 5% of job	121	30
Returned questionnaire too late to be included	4	1.0
No longer at mailing address	2	0.5

Of the 171 survey respondents working in AI/Robotics, only 121 spent more than 5 percent of their time on AI/Robotics tasks (see Figure 2). It might be argued that people who spend only a small proportion of their time performing AI/Robotics tasks should not be included in the analyses of the survey results. It may have been difficult for these people to make accurate ratings on such a small part of their jobs. In addition, these people may not be candidates for certification. Therefore, analyses were performed to determine whether the ratings differed substantially depending on the amount of time spent in AI/Robotics activities.

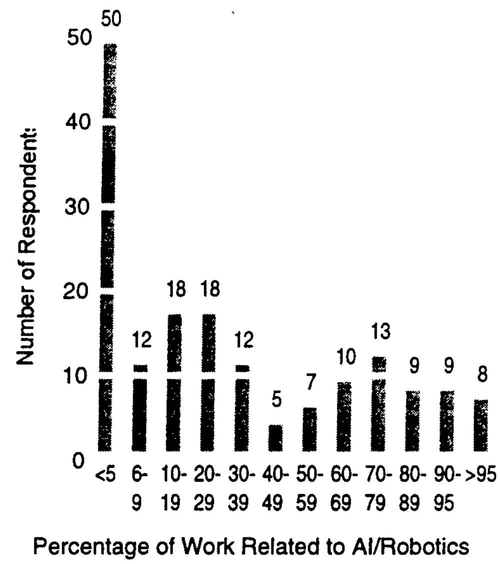


Figure 2. Job analysis survey: Histogram of percentage of AI/Robotics-related work.

For these analyses, the sample was split into 12 groups based on the amount of time devoted to AI/Robotics. The frequency distributions of the 12 groups were compared on the following variables: (a) average knowledge importance and (b) average task importance. Tasks not performed and knowledges not required were assigned a score of zero. The analyses showed that the mean for the group which spent less than five percent of their time in AI/Robotics activities had a mean much lower than the means for the other groups (see Table 11).

Table 11. Mean Task and Knowledge Ratings by Percentage of Time Spent in AI/Robotics Activities

Percentage of Time Spent in AI/Robotics Activities	Number of People In Group	Mean Task Importance	Mean Knowledge Importance
< 5%	50	0.58	0.85
6-9	12	0.91	1.46
10-19	18	1.24	1.60
20-29	18	1.42	1.43
30-39	12	1.20	1.24
40-49	5	1.28	1.54
50-59	7	1.82	1.70
60-69	10	1.91	1.92
70-79	13	1.81	1.81
80-89	9	2.10	1.99
90-95	9	2.23	1.76
>95	8	2.01	2.12

Therefore, it was decided to exclude this group from subsequent analyses of the knowledge and task ratings. That is, the analyses would include only the 121 people who spent at least five percent of their time in AI/Robotics activities. Frequency ratings are reported both including (N = 171) and excluding (N = 121) people who spent less than five percent in AI/Robotics activities.

The biographical variables are shown in Tables 12–21. In most of the tables, the rows are in descending rank order according to the value for the sample of people that spent more than five percent of their job performing AI/Robotics tasks. The average survey respondent:

- works in the Army Research Lab in AMC.
- is in the Electronics Engineer job series.
- is in the Engineer and Scientist (Non-Construction) career program.
- is a GS-11 or GS-12.
- gets most of his or her training from reading, on the job training, and conferences.
- has a Master's degree.
- has been in his or her current position for about 10 years.
- has been using AI/Robotics in his or her current position for about five years.
- does not supervise anyone.

Table 12. Job Analysis Survey: Frequencies for Career Program

Number of Respondents			
All Respondents	AI/Robotics > 5% of Job	Career Program	
137	95	16	Engineers & Scientists (Non-Construction)
11	9	34	Information Mission Area
3	3	13	Supply Management
2	2	11	Comptroller
2	2	18	Engineers & Scientists (Construction)
1	1	24	Transportation Management
1	1	26	Contracting & Acquisition
9	7		*Other*
5	1		*Missing*

Table 13. Job Analysis Survey: Frequencies for Grade Level

Number of Respondents		
All	AI/Robotics > 5% of Job	Grade Level
2	2	GS-07
17	13	GS-09
53	43	GS-11
58	40	GS-12
14	9	GS-13
11	5	GS-14
5	4	GS-15
4	1	GM-13
5	2	GM-14
2	2	GM-15

Table 14. Job Analysis Survey: Frequencies for Major Command

Number of Respondents		
All	AI/Robotics > 5% of Job	Major Command
123	87	AMC
28	20	HQDA Total
6	4	ODCSLOG
5	3	OPTEC
3	3	CAA
1	1	OCSPER
1	1	ODISC4
9	6	*Other*
3	2	*Missing*
8	6	TRADOC
4	4	Corps of Engineers
4	2	*Other*
4	2	*Missing*

Table 15. Job Analysis Survey: Frequencies for Job Series

Number of Respondents			
All Respondents	AI/Robotics > 5% of Job	Job Series	
26	18	855	Electronics Engineering
22	15	1515	Operations Research
16	12	334	Computer Specialist
16	11	830	Mechanical Engineering
14	9	180	Psychology
13	8	801	General Engineering
10	6	861	Aerospace Engineering
6	6	403	Microbiology
7	6	1550	Computer Science
5	5	850	Electrical Engineering
9	5	1310	Physics
6	4	301	Information Systems Manager
3	2	806	Materials Engineering
3	1	896	Industrial Engineering
1	1	2101	Transportation Specialist
1	1	858	Biomedical Engineering
2	1	1529	Mathematical Statistics
11	10	2130	*Other*

Table 16. Job Analysis Survey: Frequencies for Major Subordinate Command

Number of Respondents: All Respondents	Number of Respondents: AI/Robotics > 5% of Job	Major Subordinate Command
46	29	Army Research Lab (ARL)
10	10	Army Test and Evaluation Command (TECOM)
12	7	Industrial Engineering Activity (IEA)
7	4	Industrial Operations Command (IOC)
6	3	Logistics Support Activity (LOGSA)
2	2	Missile Command (MICOM)
3	2	Communications-Electronics Command (CECOM)
44	28	*Other*
41	31	*Missing*

Table 17. Job Analysis Survey: Frequencies for Source of Training

Number of Respondents: All Respondents	Number of Respondents: AI/Robotics > 5% of Job	Source of Training/Education
123	93	Reading AI/Robotics literature
128	98	On-the-job training
86	69	Attending conferences
58	49	College courses
37	34	Private providers of training (e.g., NeuralWare)
35	33	Government providers of training: Military (e.g., Army Logistics Management College)
5	5	Government providers of training: Non-military (e.g., FBI)

Notes. N = 171 for All Respondents and N = 121 for AI/Robotics > 5% of Job. Columns do not sum to these totals because respondents picked *all* training sources they used.

Table 18. Job Analysis Survey: Frequencies for Highest Level of Education Achieved

Number of Respondents		
All Respondents	AI/Robotics > 5% of Job	Highest Level of Education Achieved
7	7	Some college
4	2	Associate's degree (2-year)
20	12	Bachelor's degree (4-year)
28	21	Some graduate school
66	44	Master's degree
33	24	Doctoral degree
13	11	*Missing*

Table 19. Job Analysis Survey: Frequencies for Time in Current Position

Number of Respondents		
All Respondents	AI/Robotics > 5% of Job	Time in Current Position
4	2	Less than 6 months
5	4	6 months to less than one year
24	17	1 year to less than 3 years
21	15	3 years to less than 5 years
56	35	5 years to less than 10 years
49	38	10 or more years
12	10	*Missing*

Table 20. Job Analysis Survey: Frequencies for Years that AI/Robotics has been used in Current Position

Number of Respondents		
All Respondents	AI/Robotics > 5% of Job	Length of Time that AI/Robotics has been used in Current Position
15	4	Less than 6 months
8	4	6 months to less than one year
37	25	1 year to less than 3 years
32	28	3 years to less than 5 years
43	32	5 years to less than 10 years
18	16	10 or more years
18	12	*Missing*

Table 21. Job Analysis Survey: Frequencies for Supervisory Level

Number of Respondents		
All Respondents	AI/Robotics > 5% of Job	Supervisory Level of the Respondent
93	73	Not a supervisor
45	28	Team leader (not in an officially designated supervisory position)
16	7	First level supervisor
4	3	Second level supervisor
1	0	Above second level supervisor
12	10	*Missing*

ANALYSIS OF THE JOB ANALYSIS SURVEY RESULTS

The analysis of the responses to the job analysis survey focused on the importance ratings for the 37 tasks and the 51 knowledges. As stated above, these analyses included only the 121 respondents who spent more than five percent of their time performing AI/Robotics tasks. The purposes of the analyses were to determine which tasks and knowledges were important. The rating scales for the tasks and knowledges are shown below.

Task Importance Scale

0 - Not performed
1 - Much less a part of the job than most other AI/Robotics tasks
2 - Somewhat less a part of the job than most other AI/Robotics tasks
3 - A part of the job about the same amount as most other AI/Robotics tasks
4 - Somewhat more a part of the job than most other AI/Robotics tasks
5 - Much more a part of the job than most other AI/Robotics tasks

Knowledge Importance Scale

0 - Not required at all to perform the job.
1 - Much less important than most other knowledges
2 - Somewhat less important than most other knowledges
3 - About the same importance as most other knowledges
4 - Somewhat more important than most other knowledges
5 - Much more important than most other knowledges

Level of Knowledge Required

1 - General understanding
2 - Intermediate level of knowledge
3 - Advanced level of knowledge

The identification of the important tasks and knowledges was complicated by the diverse nature of the field of AI/Robotics. Only a few of the AI/Robotics tasks and knowledges listed in the survey were expected to be relevant for any one person. Thus few tasks or knowledges were expected to receive high ratings.

As shown below, the survey responses found both these expectations to be true. About half of the tasks and half of the knowledges on the survey were relevant to the average person's job. As a consequence, *every* single task had a mean rating across the respondents as being a part of the job *less* than most other AI/Robotics tasks; similarly, *every* single knowledge had a mean rating across the respondents as being *less* important than most other AI/Robotics knowledges.

- The mean number of tasks, out of the 37 in the survey, not performed = 18.
- The mean number of knowledges, out of the 51 in the survey, not required = 25.
- The mean task importance rating (see the rating scale above) = 2.8.
- The mean knowledge importance rating (see the rating scale above) = 2.5.

To gain other perspectives on the ratings, four variations of these ratings were computed for each task and knowledge. These four variations are described below for the knowledge importance ratings. Similar variations were computed for the level of knowledge required and task importance. When computing the mean rating for a knowledge across the respondents, a respondent's score was designated as *missing* if he/she did not rate the knowledge. That is, these respondents were excluded when computing the mean rating for that knowledge.

A rating of zero on a task meant that the respondent did not perform that task; a rating of zero on a knowledge meant that the knowledge was not required at all to perform the job. These zero ratings were dealt with in two different ways when the mean ratings were computed across the respondents: they were either ignored or included. When zero ratings were *ignored*, a rating of zero was considered to be missing: respondents who gave a zero rating to a knowledge were excluded when the mean was computed for that knowledge. A mean knowledge importance which is computed this way answers the question: "Among the respondents who use this knowledge, how important is it?" When zero ratings were *included*, a rating of zero was included in the computation of the mean for that knowledge. A mean knowledge importance which is computed this way answers the question: "What is the average importance of this knowledge across all the respondents?" If a knowledge is required by only a few people, but rated as being very important by every person who uses it, then that knowledge would have a high mean importance ignoring zero but a low mean importance including zero. Means were computed this way for both tasks and knowledges.

When computing the means, the ratings were either weighted or unweighted. When computing a weighted mean, a knowledge was assigned a score equal to the product of the rating and the proportion of the respondent's time spent in AI/Robotics activities. This weighting scheme assumes that more attention should be paid to respondents who spend a lot of their time in AI/Robotics activities.

- **ignore zero, unweighted:** A knowledge Not Required was given a score of missing. A required knowledge was assigned a score equal to the rating assigned. Thus the range of possible values = missing, 1–5.
- **include zero, unweighted:** A knowledge Not Required was given a score of zero. A required knowledge was assigned a score equal to the rating assigned. Thus the range of possible values = missing, 0–5.
- **ignore zero, weighted:** A knowledge Not Required was given a score of missing. A required knowledge was assigned a score equal to the product of the rating and the proportion of the respondent's time spent in AI/Robotics activities. Thus the range of possible values = missing, .075–4.875.
- **include zero, weighted:** A knowledge Not Required was given a score of zero. A required knowledge was assigned a score equal to the product of the rating and the

proportion of the respondent's time spent in AI/Robotics activities. Thus the range of possible values = missing, .075–4.875.

One more perspective was gained by doing separate mean importance ratings for (a) respondents who spent *less* than half of their time doing AI/Robotics and (b) respondents who spent *more* than half of their time doing AI/Robotics. All perspectives were considered when determining the important tasks and the critical knowledges.

In general, the most consideration should probably be given to ratings that are unweighted, include zero, and involve people who spent at least 50% of their time in AI/Robotics activities.

Descriptive Statistics

Task Importance

The purpose of the task ratings was to determine the critical tasks (these are listed in Table 22). These critical tasks would then be used in a questionnaire that linked the competencies to the critical tasks. The mean task importance ratings are shown in Table A-1, and their ranks are in Table A-2. In the tables, the tasks are listed in order of their mean importance ratings. Specifically they are listed in order of the mean of the ranks on the first four variables listed in the table. Seventeen of these tasks were identified as being critical.

In determining which tasks were critical, the following factors were considered: (a) large jumps in the ratings between two tasks, and (b) the consistency of the rankings of the tasks across all the variations of mean importance. In addition, more attention was paid to the ratings from the people who spent at least 50% of their time in AI/Robotics, the unweighted means, and the means that included items with ratings of zero.

Competencies

Each competency was rated on two scales: *importance* and *level of knowledge required.* The main purpose of the importance ratings was to help identify which competencies should be included in the certification standards. The main purpose of the level required ratings would be to help the certification panel determine the level of knowledge that a certificant should have in a specific competency. It would also be useful in determining which competencies should be included in the certification standards.

The mean knowledge importance ratings are shown in Table A-3, and the ranks of the means are in Table A-4. In the tables, the competencies are listed in order of their mean importance ratings. Specifically they are listed in order of the mean of the ranks on the first four variables listed in the table.

At this stage in the project, no competencies were eliminated. These analyses would guide the task force's decision regarding which competencies to include in the certification standards, additional information could affect the decision.

Table 22. List of Critical Tasks

1. Identify and assess opportunities to apply AI/robotics to improve processes and systems.

2. Perform overall project management (e.g., monitor budgets and timelines) of funded AI/Robotics efforts.

3. Manage daily functions of funded AI/robotics efforts.

4. Read research articles, reports, and others sources (e.g., internet messages) to keep abreast of current and emerging AI/Robotics practices and technologies.

5. Oversee contractors performing AI/robotics work.

6. Seek and maintain liaisons with academia/industry/government to keep abreast of current and emerging AI/Robotics practices and technologies.

7. Build systems (e.g., computer programs) using AI/robotics principles and techniques.

8. Select available knowledge sources (e.g., subject matter experts, data).

9. Assist users in refining AI/robotics system requirements.

10. Evaluate proposals and plans for AI/robotics projects and programs.

11. Develop AI/robotics system specifications (e.g., for environment, software, hardware, and interface).

12. Identify, evaluate, and recommend procurement of specific hardware and software tools.

13. Evaluate AI/robotics software, hardware, and tools.

14. Integrate AI/robotics components into systems.

15. Perform knowledge engineering (e.g., interviewing subject matter experts, evaluating data).

16. Attend courses, symposia, seminars, and conferences to keep abreast of current and emerging AI/Robotics practices and technologies.

17. Test and evaluate AI/robotics components and/or systems.

Factor Analysis

In order to gain insight into the dimensions underlying the competencies, a factor analysis was performed. The analysis used a principal axis extraction and oblique Harris-Kaiser rotation (allowing the factors to be maximally oblique). It was decided to extract four factors because of a discontinuity between the fourth and fifth eigenvalues.

The four factors were Expert Systems & Knowledge Bases, Modeling and Simulation, Computer Science, and Robotics. Table 23 shows the factor pattern matrix. Tables 24–27 show each competency listed within the factor on which it loaded highest. Tables 24–27 also show the mean importance ratings and ranking for each competency.

Within each factor, the competencies were put into two or three groups. In determining which competencies to place in each group, the distributions of the means were examined for relatively large jumps between the means of consecutively ranked knowledges. Correlation analyses showed that the knowledges tended to have similar ranks on all of the importance measures.

The task force discussed the competencies at two meetings to decide which competencies would be used in the certification process. The task force concurred with the dimensions determined by the factor analysis. They considered the Systems & Knowledge Bases dimension to represent the core competencies of AI/Robotics whereas the other three dimensions contained supplemental competencies. That is, the core competencies should be common to all people working in AI/Robotics whereas supplemental competencies were probably relevant only to certain types of positions.

Table 23. Job Analysis Survey: Factor Loadings for Unweighted Competency Importance Ratings

Overall Item Rank	Item	KSA Description	Factor Loadings: Simulation & Modeling	Expert Systems / Knowledge Bases	Computer programming, software, & hardware	Robotics
24	48	research design methods	**80**	-4	-13	7
13	50	applied mathematics (e.g., calculus, algebra) and statistics	**78**	-6	-1	-4
1	47	modeling	**77**	13	-8	1
29	49	measurement	**76**	-18	-10	14
4	46	simulation	**73**	5	-1	9
21	51	optimization techniques	**65**	9	19	-13
5	44	conceptual modeling of problems and solutions	**64**	18	18	-27
3	9	knowledge bases	-1	**86**	7	-18
11	13	knowledge engineering	1	**85**	2	-27
15	25	knowledge representation techniques and principles	0	**81**	17	-28
2	1	expert systems	5	**80**	-4	-18
47	37	case-based reasoning software	-9	**76**	0	4
48	15	frame-based systems	-19	**76**	-1	13
35	11	AI shells	5	**75**	-4	-17
25	7	heuristic algorithms	19	**74**	-27	4
42	5	agent architectures	-17	**73**	-9	19
34	38	the application of commercial AI tools (e.g., preprocessing tools, AI shells)	8	**73**	-5	-11
7	12	methodologies for integrating AI with modeling, optimization, mathematical, statistical, or other computer programs	26	**69**	-2	-14
6	10	the basic principles of AI	-2	**69**	2	11
45	6	genetic algorithms	5	**66**	-26	17
49	36	expert system blackboard software	-11	**66**	2	4
18	20	search strategies	16	**65**	11	-4
46	14	first-order logic	-4	**64**	0	21
37	3	path planning	6	**63**	-21	29
20	24	distributed databases	-17	**61**	40	-14
41	4	blackboard theory	-11	**59**	3	24
32	2	neural networks	20	**57**	-27	28
31	8	fuzzy logic	17	**56**	-19	26
14	33	principles of object-oriented programming	-5	**51**	**51**	-23
9	35	knowledge representation tools and arthitectures (e.g., relational databases)	9	**51**	**48**	-43
43	28	natural language	-19	47	10	26
51	39	machine translation of languages	0	28	16	20

table continues . . .

			Factor Loadings			
Overall Item Rank	Competency		Simulation & Modeling	Expert Systems / Knowledge Bases	Computer programming, software, & hardware	Robotics
10	32	computer system software component interfaces	-1	-12	**96**	0
19	30	computer operating systems	-10	-5	**83**	-6
23	31	computer system hardware component interfaces	-6	-23	**82**	29
22	29	computer system architectures	-16	22	**71**	12
16	34	high-level computer programming languages (e.g., C, LISP, ADA)	12	5	**63**	-10
8	26	software engineering	13	21	**61**	-12
17	40	real time programming	14	-5	**55**	20
38	45	parallel processing techniques	12	13	**53**	13
28	43	data acquisition hardware and software	40	-30	39	26
12	41	sensors	12	-29	5	**79**
33	18	sensor fusion	5	17	-7	**76**
26	21	the basic principles of robotics	3	-18	-2	**76**
44	22	robot navigation	-3	-17	18	**73**
39	16	control theory	-5	21	-5	**68**
40	27	computer vision	-6	-11	27	**68**
50	19	message fusion	-14	48	-10	**55**
27	17	embedded systems	-10	38	11	**53**
30	42	image processing software and hardware	26	-10	19	**53**
36	23	hybrid systems	-1	41	-15	41

Notes. The factor loadings indicate the extent to which a competency is related to each of the four factors. A boldfaced factor loading indicates that this competency can be considered to be part of this factor. Shading is added to enhance readability; it does *not* signify any kind of grouping. Overall item rank is based on the mean importance (unweighted, include zero) for AI > 50%.

The task force made the following decisions concerning the list of competencies. First, the task force decided to eliminate all of the competencies within the *simulation and modeling* dimension except for *conceptual modeling of problems and solutions* (which the task force concluded is important in AI/Robotics). Although simulation and modeling are often used in conjunction with AI/Robotics, they are not considered to be part of AI/Robotics. Both of these competencies had been rated highly. Second, the task force concluded that some of the knowledges related to computer hardware and software were not specifically related to AI/Robotics and thus were also eliminated. The task force eliminated mathematics, statistics, and measurement for two reasons: they were in the simulation and modeling dimension and they were not specific to AI/Robotics.

Table 24. Job Analysis Survey: Mean Competency Importance Ratings for Expert Systems & Knowledge Bases

Rank	Item	Competency Description	AI < 5%	AI 5-50%	AI > 50%
1	1	expert systems	1.20	1.90	2.72
2	9	knowledge bases	1.02	1.84	2.67
3	33	principles of object-oriented programming	1.00	1.58	2.55
4	25	knowledge representation techniques and principles	1.02	1.45	2.53
5	10	the basic principles of AI	1.37	1.92	2.44
6	12	methodologies for integrating AI with modeling, optimization, mathematical, statistical, or other computer programs	1.08	1.67	2.44
7	35	knowledge representation tools and architectures (e.g., relational databases)	1.10	1.71	2.40
8	13	knowledge engineering	1.06	1.68	2.33
9	20	search strategies	0.44	1.39	2.20
10	24	distributed databases	0.98	1.15	2.15
11	7	heuristic algorithms	0.76	1.00	1.79
12	8	fuzzy logic	0.73	1.30	1.65
13	2	neural networks	1.02	1.44	1.65
14	38	the application of commercial AI tools (e.g., preprocessing tools, AI shells)	0.53	1.13	1.59
15	11	AI shells	0.51	1.36	1.57
16	23	hybrid systems	0.21	1.10	1.56
17	3	path planning	0.39	1.29	1.56
18	4	blackboard theory	0.27	0.69	1.37
19	5	agent architectures	0.27	0.62	1.37
20	28	natural language	0.41	0.72	1.29
21	6	genetic algorithms	0.31	0.94	1.20
22	14	first-order logic	0.41	1.14	1.13
23	37	case-based reasoning software	0.35	0.79	1.11
24	15	frame-based systems	0.37	0.73	1.09
25	36	expert system blackboard software	0.24	0.65	1.05
26	39	machine translation of languages	0.39	0.79	0.75

Notes. Rank is based on the AI > 50% mean. Shading is added to enhance readability; it does *not* signify any kind of grouping. Blank rows separate sets of competencies according to their importance.

Table 25. Job Analysis Survey: Mean Competency Importance Ratings for Simulation & Modeling

Rank	Item	Competency Description	AI < 5%	AI 5-50%	AI > 50%
1	47	modeling	3.26	3.48	3.76
2	46	simulation	3.04	3.36	3.62
3	44	conceptual modeling of problems and solutions	2.43	3.00	3.18
4	50	applied mathematics (e.g., calculus, algebra) and statistics	2.83	3.70	2.76
5	51	optimization techniques	2.09	2.88	2.65
6	48	research design methods	3.09	2.88	2.62
7	49	measurement	2.61	2.69	2.44

Notes. Rank is based on the AI > 50% mean. Blank rows separate sets of competencies according to their importance.

Table 26. Job Analysis Survey: Mean Competency Importance Ratings for Computer Science

Rank	Item	Competency Description	AI < 5%	AI 5-50%	AI > 50%
1	32	computer system software component interfaces	3.09	3.50	3.46
2	26	software engineering	2.64	3.33	3.39
3	34	high-level computer programming languages (e.g., C, LISP, ADA)	2.64	3.17	3.36
4	31	computer system hardware component interfaces	3.18	3.39	3.14
5	29	computer system architectures	2.91	3.22	3.07
6	40	real time programming	1.45	2.50	3.04
7	30	computer operating systems	3.27	3.39	3.00
8	45	parallel processing techniques	0.91	2.61	2.50
9	43	data acquisition hardware and software	2.45	2.72	2.25

Notes. Rank is based on the AI > 50% mean. Blank rows separate sets of competencies according to their importance.

Table 27. Job Analysis Survey: Mean Competency Importance Ratings for Robotics

Rank	Item	Competency Description	AI < 5%	AI 5-50%	AI > 50%
1	41	sensors	3.58	3.06	3.58
2	18	sensor fusion	2.17	2.29	2.73
3	21	the basic principles of robotics	1.18	2.45	2.61
4	42	image processing software and hardware	1.73	2.27	2.58
5	17	embedded systems	1.08	2.29	2.53
6	16	control theory	2.08	2.47	2.40
7	27	computer vision	0.83	1.73	2.32
8	22	robot navigation	1.36	1.91	2.10
9	19	message fusion	1.83	1.61	1.53

Notes. Rank is based on the AI > 50% mean. Shading is added to enhance readability; it does *not* signify any kind of grouping. Blank rows separate sets of competencies according to their importance.

Subgroup Analyses

Several other analyses were conducted to look at differences between subgroups. Because of the small sample, few meaningful analyses could be done. The subgroup analyses examined the competency rating profiles. They used the unweighted rating measure that included competencies with zero values. The profiles are shown in Figures 3–7.

For the robotics profile chart, people who did little work in this area were excluded (i.e., people whose sum of scores on the robotics competencies was 9 or less). Similar criteria were used to exclude people from the profile charts for computer science (i.e., people whose sum of scores on the computer science competencies was 15 or less), and simulation and modeling (i.e., people whose sum of scores on the simulation and modeling competencies was 11 or less).

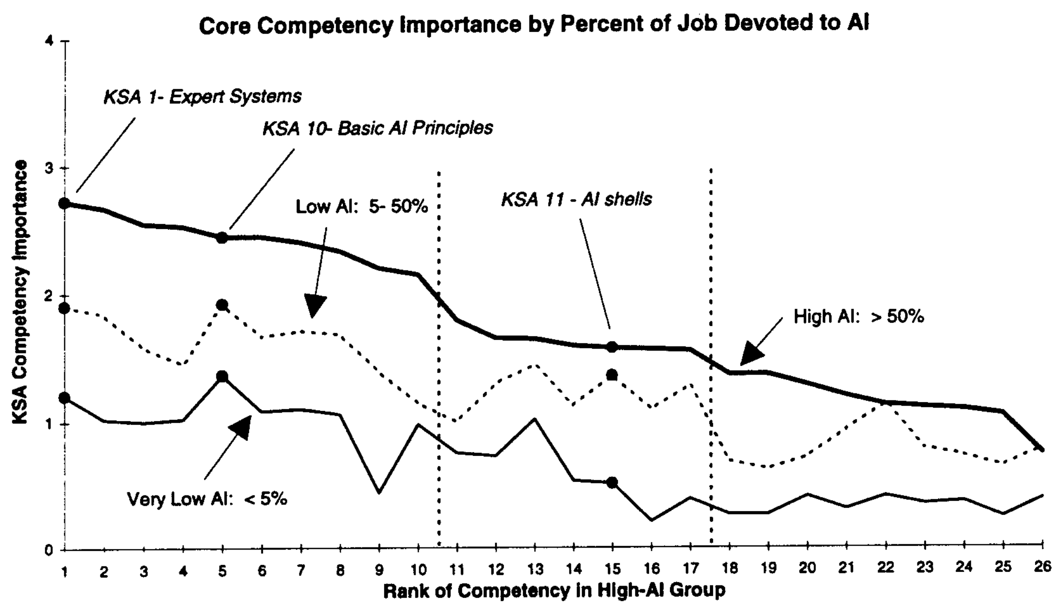
The groups profiled and the competencies included in the profiles were:

- Competency rating by the amount of time spent in AI/Robotics activities for all competencies: very low (< 5%) vs. low (5–50%) vs. high (> 50%)
- Competency rating by the amount of time spent in AI/Robotics activities for Expert Systems / Knowledge Bases competencies: very low (< 5%) vs. low (5–50%) vs. high (> 50%)
- Competency rating by the amount of time spent in AI/Robotics activities for Computer Science competencies: very low (< 5%) vs. low (5–50%) vs. high (> 50%)
- Competency rating by the amount of time spent in AI/Robotics activities for Robotics competencies: very low (< 5%) vs. low (5–50%) vs. high (> 50%)
- Competency rating by the amount of time spent in AI/Robotics activities for Simulation and Modeling competencies: very low (< 5%) vs. low (5–50%) vs. high (> 50%)

- Competency rating by the importance of doing basic research (task #37): none (not performed) vs. minimal (performed much less than other AI/Robotics tasks) vs. significant (performed somewhat less to much more than other AI/Robotics tasks)

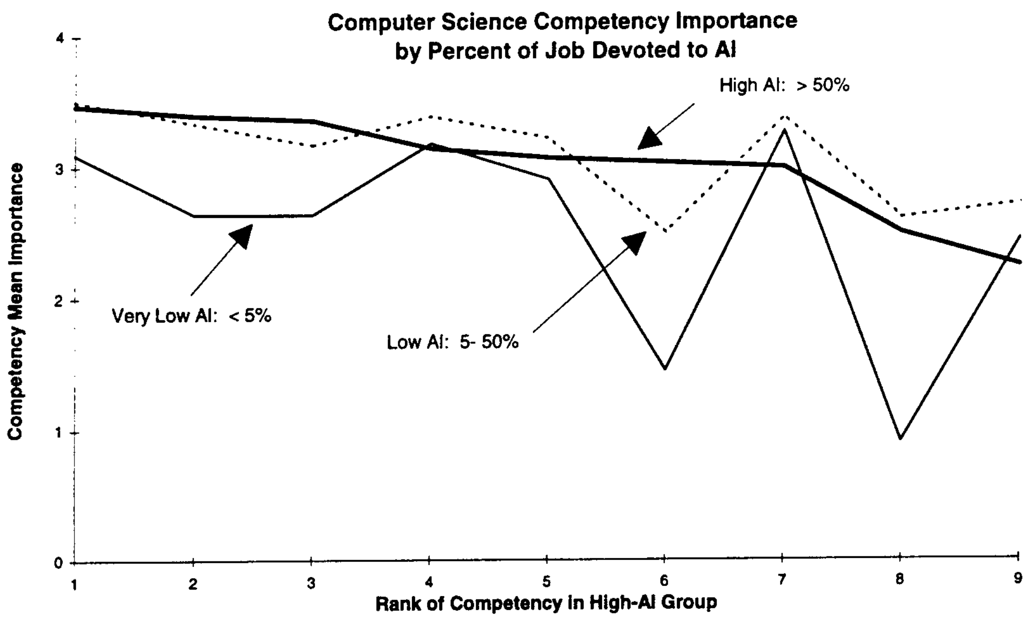
The profile charts show that the *patterns* of the competency profiles are similar among the three groups that were formed based on the amount of time spent in AI/Robotics activities. The *elevations* of the profiles did differ, however. That is, people who spent a lot of time in AI/Robotics activities tended to rate the knowledges higher.

The competency profile chart which splits the sample into three groups based on the amount of basic research that they do shows that the profiles look very similar, overall, for the more important competencies. For the less important competencies, people who do a lot of basic research considered these competencies more important than did the other people.



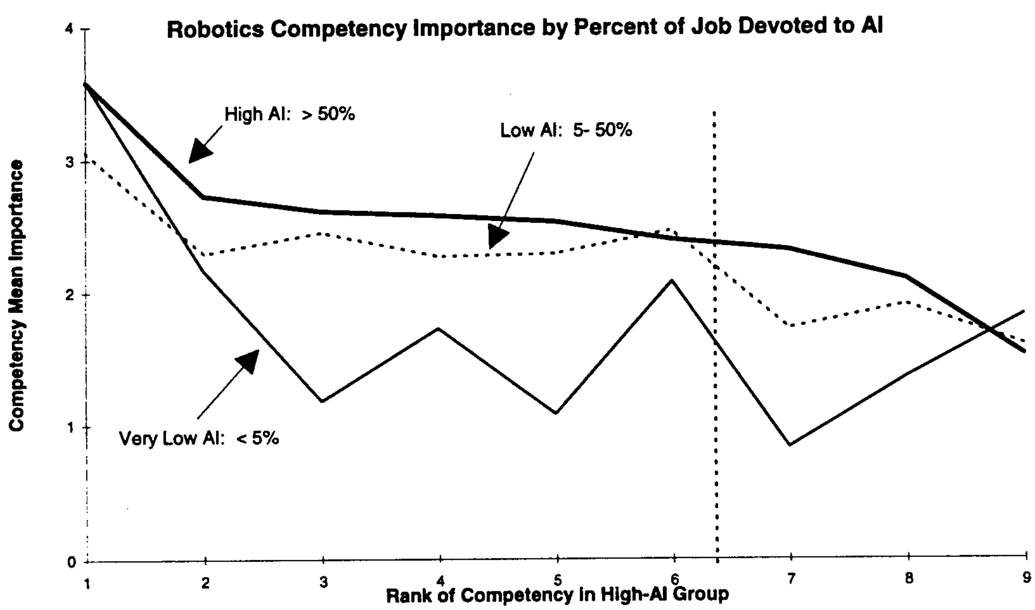
Note: n = 49 for Very Low, n = 65 for Low, and n = 56 for High.

Figure 3. Profile for all competencies of mean importance by AI/Robotics percentage.



Note: n = 11 for Very Low, n = 18 for Low, and n = 28 for High.

Figure 4. Profile for computer science of mean importance by AI/Robotics percentage.



Note: n = 12 for Very Low, n = 34 for Low, and n = 31 for High.

Figure 5. Profile for robotics competencies of mean importance by AI/Robotics percentage.

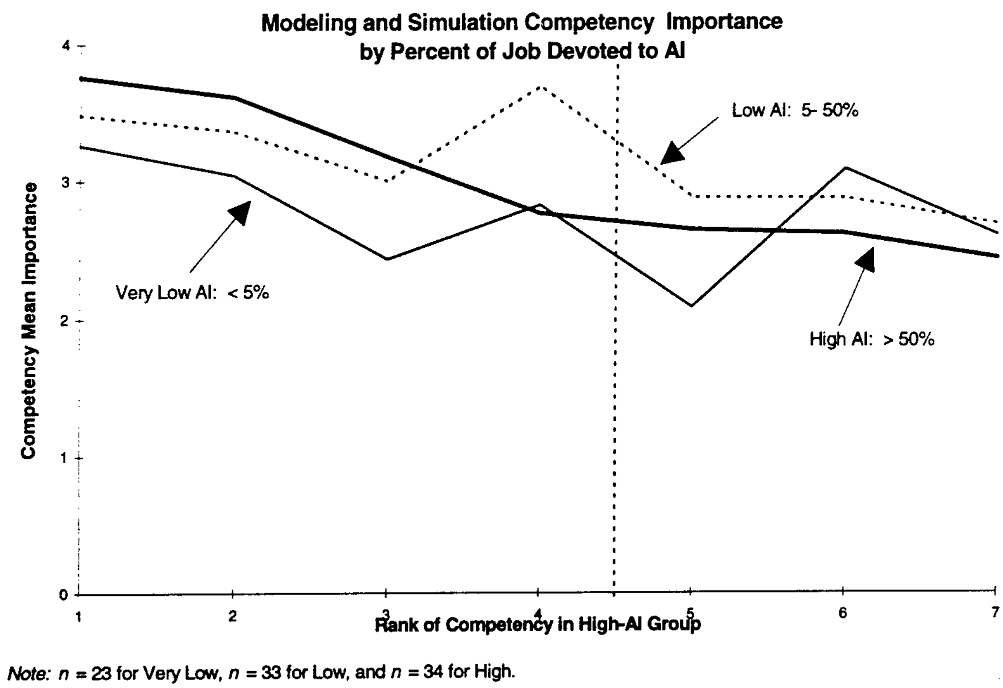


Figure 6. Profile for modeling & simulation competencies of importance by AI/Robotics percentage.

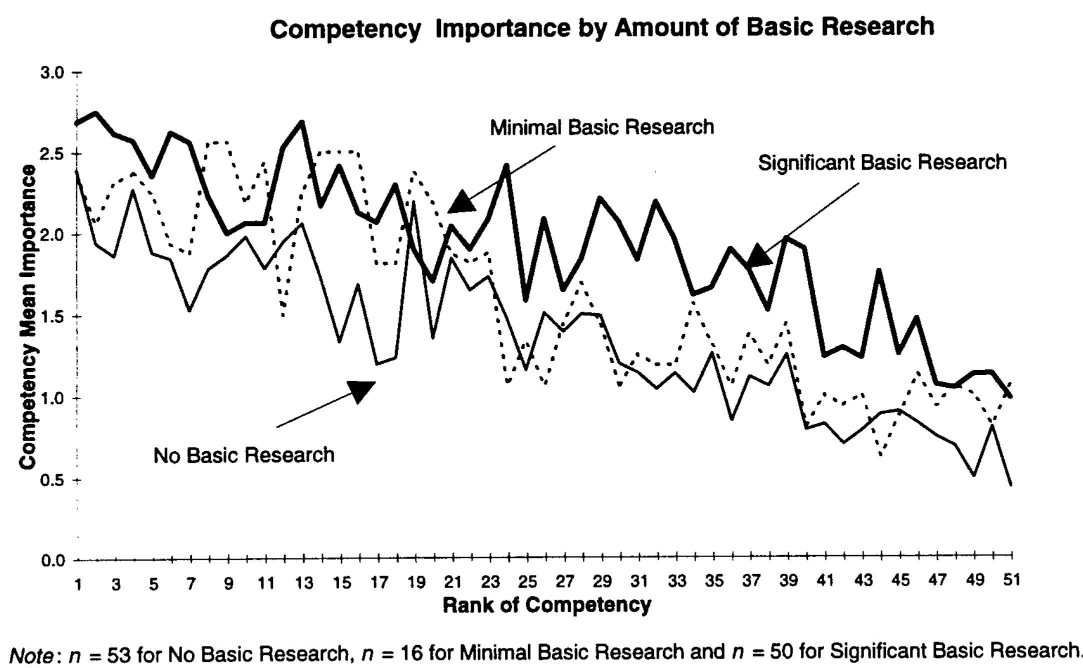


Figure 7. Profile for all competencies of importance by basic research importance.

ESTABLISHMENT OF THE TASK-COMPETENCY LINKAGES

A competency-to-task linkage questionnaire was developed to ensure a close linkage between the competencies and the critical tasks. The questionnaire was mailed to the task force members with written instructions. For each of the 17 critical tasks, the task force members rated how important each of the core and supplemental competencies were in performing that task (the questionnaire is in Appendix D).

The raters used the following scale to rate each competency:

0	**not needed**	This competency is *not needed* to perform the task. Having this competency would make no difference in the performance of the task.
1	**helpful**	This competency is *helpful* in performing the task, but not essential. The task could be performed without this competency, but the task would be more difficult or time-consuming.
2	**essential**	This competency is *essential* to the performance of the task. Without this competency, you would not be able to perform the task.
?	**don't know**	If you are unfamiliar with either the task or the competency, then write a question mark in the square.

All four task force members completed the questionnaire. Six of the core competencies received several ratings of essential. That is, each of these six competencies were considered essential to successfully performing some critical tasks. This was true for every rater. Two of the raters gave the core competency, *search strategies*, no *essential* ratings. At the final workshop, this competency was changed to a supplemental competency with the full agreement of all task force members.

All of the supplemental competencies received at least some ratings of helpful. Thus, each of the supplemental competencies was considered helpful for performing some critical tasks.

CONSTRUCTION OF THE COURSE INFORMATION BASE

The competency standards would require that candidates for certification provide evidence that they had acquired a competency. Two types of evidence would be acceptable: evidence of training/education, and evidence of relevant experience. To help both the candidates and the certification review panel, a database of known courses in AI/Robotics was developed.

The last page of the job analysis questionnaire asked respondents to list the names and sources of all their AI/Robotics courses. One of the task force members collected these completed pages and gathered information about these courses. There were initially over 250 courses. Courses that were obviously unrelated to the competencies were eliminated, as were courses for which information could not be gathered.

The task force met on October 22, 1996, to discuss these courses and link them to the competencies. The meeting began with a list of 100 courses. Because this list was much too long to link to the 32 competencies, similar courses were grouped together. One course in each group was designated as the prototype course for that group.

Then the task force linked each of the 20 prototype courses, via consensus, to the competencies. For each competency, each prototype course was determined to provide either (a) no credit, (b) partial credit, or (c) full credit towards that competency. A course with partial credit could be combined with sufficient experience to fulfill the requirements for a competency. Similarly, a course with full credit would completely fulfill the requirements for that competency.

A course information database was constructed by the Army Artificial Intelligence Center using MS Access. For each course, the following information is provided: course title, list of similar courses, the prototype course, list of relevant competencies with their level of credit provided by the course (partial or full), and a course description. This course information is provided in the certification standards (see Appendix E).

COMPETENCY STANDARD RECOMMENDATIONS

Process for Determining Recommended Standards

After the job analysis results were reviewed by the task force, the certification standards were developed via four meetings and a mailout. Parts of this process have been described above. This section provides an integrated description of the process. Parts that have been described in detail above will only be summarized here.

Selecting the Competencies for Certification

The results of the job analysis survey were presented to the task force September 25, 1996. On September 30, the task force met to discuss the competencies. The competencies within each of the four dimensions obtained via the factor analysis were examined separately: Core, Simulation and Modeling, Computer Science, and Robotics.

As mentioned previously, all of the competencies, except one (conceptual modeling of problems and solutions) within the simulation and modeling dimension were discarded because they are not considered part of AI/Robotics. Some of the computer science competencies were dropped for the same reason.

In the robotics dimension, all of the competencies were kept except for message fusion and embedded systems. Message fusion was rated much lower than the other competencies, and embedded systems was determined to be redundant. Computer vision and image processing were combined to form a single competency.

In the computer science dimension, all the competencies were determined to be not specifically related to AI/Robotics except for *high-level computer programming languages*. Thus, only one competency from this dimension was kept.

In the core dimension, the five lowest-rated competencies were discarded. In addition, *agent architectures* was deleted because it was redundant, and *distributed databases* was deleted because it was considered not to be an area of AI/Robotics. *Speech recognition / synthesis* and *machine learning* were added because they were considered important by the task force but were not on the survey.

The task force rearranged the retained competencies into two categories: core competencies and supplemental competencies. The first category represented competencies that would be used in most types of AI/Robotics applications, whereas the second category included competencies that would likely be used only in specialized applications. The task force decided that certificants should possess all of the core competencies and at least three of the supplemental ones.

Linking Courses to Competencies

At the next workshop, held October 22, 1996, the task force reviewed the course information and linked the courses to the competencies. Twenty prototype courses were linked to the competencies via consensus. Each course was identified as giving partial or full credit for a competency. The task force also developed a general description of the level of performance and capabilities in AI/Robotics that the certificants should be demonstrated to be certified.

Defining Standards for Experience

The task force and three additional Army civilians working in AI/Robotics developed most of the standards for experience at a two-day workshop held November 20–21, 1996. They developed the outline for general standards for experience and combinations of experience and course work. Examples of sufficient and insufficient experience were also developed for each of the core competencies.

After the meeting, HumRRO refined the standards and sent a mailout (on February 20, 1997) to the task force members for review. The task force members reviewed the standards and suggested a few minor changes. As part of the mailout, the task force members also completed a questionnaire to link the competencies to the critical tasks.

Finalizing the Standards

The task force met one more time, on April 7, 1997. The sponsor had written definitions for the competencies. Prior to the meeting, the task force members had read the definitions and offered suggestions. The definitions were reviewed at the meeting, and minor modifications were made.

The changes to the definitions elicited a couple of changes to the competencies. First, *AI shells* was discarded because it was considered redundant. Next, the two competencies concerning knowledge representation were combined into one competency.

Search strategies was changed from a core to a supplemental competency. After observing that this competence was considered helpful but not essential to performing critical tasks, the task force members concurred that it should be considered supplemental. Based on the definitions of the competencies, minor changes were made to the wording in some of the competency titles.

The recommended *Standards for the Certification of Civilians in the U.S. Army in Artificial Intelligence* are in Appendix E.

Recommendations for Implementing the Certification Standards

Issues are bound to surface when the new certification program is instituted. For example, no set of standards can be completely objective and cover all situations. Therefore, some subjective decisions will have to be made. Some guidelines are provided below that should help both the applicants and the review panel in the certification process. These guidelines were reviewed and accepted by the task force at the final project meeting.

Guidelines for Certification Candidates

It is important that certification candidates be given sufficient information to allow them to understand the certification process, the competency standards, and procedures for preparing their application packages. To do this, a candidate handbook should be developed that includes the following items:

- Purpose of the certification process
- Significance of the credential (i.e., what it means and what it does not mean)
- Full description of the requirements for certification
- Detailed instructions for preparing submission packages
- Timeline for submitting and evaluating packages
- Description of the process that will be used to evaluate the submission packages
- Who to contact with questions

Much of the information for the handbook can be drawn from the competency standards. It would be hard to imagine providing too much information to candidates, and too little information will result in candidates preparing packages that have too much or too little detail for the reviewers.

Guidelines for the Review Panel

The competency standards (see Appendix D) discuss how the submission packages for AI/robotics specialty certification candidates should be evaluated. It is recommended that each submission package be reviewed by three persons. Each reviewer should evaluate a package independently and then the three pass/fail decisions collated. If all three reviewers do not agree on the overall pass/fail decision, the reviewers should meet to review the package as a group and reach a consensus decision.

To assure the fairness and integrity of the certification process, it is critical that reviewers adhere closely to the evaluation guidelines. This is particularly important if a reviewer's internal standards of competence tend to be higher or lower than those reflected in the guidelines. Adherence to the guidelines will also help to assure that reviewers focus on evidence associated with the relevant competencies and ignore other factors (e.g., neatness) when evaluating the submission packages. If there is insufficient information on which to evaluate a candidate on one or more competencies, the review panel must request additional information or fail the candidate. Reviewers should not infer information that is not provided.

APPENDIX A. Tables of Ratings Results from Job Analsis Survey

Table A-1. Job Analysis Survey: Mean Task Importance

Final Rank	Task	All Respondents (n = 121) unweighted ignore zero		All Respondents (n = 121) weighted ignore zero		Respondents with AI/Robotics < 50% (n = 65) unweighted ignore zero		Respondents with AI/Robotics < 50% (n = 65) weighted ignore zero		Respondents with AI/Robotics > 50% (n = 56) unweighted ignore zero		Respondents with AI/Robotics > 50% (n = 56) weighted ignore zero	
		ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero
1	11 identify and assess opportunities to apply AI/Robotics to improve processes and systems.	2.98	2.77	1.59	1.48	2.83	2.52	0.68	0.61	3.13	3.06	2.51	2.46
2	16 perform overall project management (e.g., monitor budgets and timelines) of funded AI/Robotics efforts.	3.23	2.07	1.82	1.17	2.93	1.55	0.68	0.36	3.46	2.67	2.72	2.10
3	17 manage daily functions of funded AI/Robotics efforts.	3.00	2.07	1.81	1.25	2.47	1.35	0.60	0.33	3.39	2.90	2.70	2.31
4	10 read research articles, reports, and other sources (e.g., internet messages) to keep abreast of current and emerging AI/Robotics practices and technologies.	2.77	2.63	1.52	1.45	2.40	2.18	0.59	0.53	3.15	3.15	2.50	2.50
4	21 oversee contractors performing AI/Robotics work.	3.01	2.15	1.59	1.14	3.00	1.90	0.72	0.45	3.02	2.43	2.37	1.90
6	7 seek and maintain liaisons with academia/industry/government to keep abreast of current and emerging AI/Robotics practices and technologies.	2.69	2.16	1.49	1.20	2.47	1.74	0.60	0.42	2.88	2.64	2.28	2.08
7	28 build systems (e.g., computer programs) using AI/Robotics principles and techniques.	2.75	1.68	1.61	0.98	2.35	1.16	0.53	0.26	3.05	2.27	2.42	1.80
8	24 select available knowledge sources (e.g., subject matter experts, data).	2.64	1.94	1.40	1.03	2.44	1.59	0.55	0.36	2.82	2.35	2.18	1.82
9	27 assist users in refining AI/Robotics system requirements.	2.51	1.79	1.50	1.07	2.14	1.21	0.46	0.26	2.78	2.43	2.24	1.96
10	12 evaluate proposals and plans for AI/Robotics projects and programs.	2.57	1.87	1.40	1.02	2.57	1.64	0.62	0.39	2.58	2.15	2.08	1.73
11	12 develop written or oral proposals to obtain funds for of AI/Robotics projects and programs.	2.57	1.69	1.45	0.95	2.25	1.31	0.56	0.33	2.86	2.13	2.26	1.68
11	24 develop AI/Robotics system specifications (e.g., for environment, software, hardware, and interface).	2.52	1.76	1.40	0.98	2.32	1.40	0.58	0.35	2.69	2.16	2.10	1.68
13	23 conduct basic research in AI/Robotics.	2.62	1.45	1.51	0.84	2.52	1.08	0.58	0.25	2.69	1.88	2.15	1.50
14	15 identify, evaluate, and recommend procurement of specific hardware and software tools.	2.47	1.87	1.34	1.01	2.33	1.53	0.54	0.35	2.60	2.27	2.03	1.77
15	30 evaluate AI/Robotics software, hardware, and tools.	2.36	1.92	1.33	1.09	2.16	1.48	0.53	0.36	2.52	2.43	1.98	1.91
15	31 integrate AI/Robotics components into systems.	2.48	1.75	1.38	0.97	2.32	1.40	0.58	0.35	2.61	2.14	2.04	1.67
17	18 write technical papers, reports, and journal articles on AI/Robotics efforts.	2.47	1.42	1.53	0.88	2.25	0.98	0.63	0.28	2.63	1.92	2.15	1.56
18	26 perform knowledge engineering (e.g., interviewing subject matter experts, evaluating data).	2.51	1.72	1.34	0.92	2.51	1.48	0.57	0.34	2.50	2.00	1.99	1.59

table continues . . .

Final Rank	Task	All Respondents (n = 121)				Respondents with AI/Robotics < 50% (n = 65)				Respondents with AI/Robotics > 50% (n = 56)			
		unweighted		weighted		unweighted		weighted		unweighted		weighted	
		ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero
19	9 attend courses, symposia, seminars, and conferences to keep abreast of current and emerging AI/Robotics practices and technologies.	2.35	1.89	1.29	1.04	2.20	1.60	0.54	0.40	2.49	2.23	1.98	1.77
19	34 test and evaluate AI/Robotics components and/or systems.	2.39	1.61	1.43	0.96	2.03	1.13	0.52	0.29	2.67	2.14	2.14	1.72
21	37 upgrade AI/Robotics systems (e.g., add new capabilities).	2.47	1.60	1.41	0.91	2.18	1.17	0.51	0.28	2.70	2.07	2.12	1.63
22	22 oversee staff performing AI/Robotics work.	2.48	1.41	1.43	0.81	2.13	1.05	0.50	0.25	2.78	1.82	2.22	1.45
23	19 give briefings on AI/Robotics-related efforts (e.g., to higher command levels).	2.42	1.73	1.32	0.95	2.25	1.43	0.52	0.33	2.58	2.07	2.04	1.64
24	35 transition AI/Robotics system operation knowledge from design team to end user.	2.40	1.41	1.43	0.84	2.00	0.92	0.44	0.20	2.68	1.96	2.14	1.56
25	20 develop and revise statements of work related to AI/Robotics.	2.44	1.62	1.30	0.86	2.46	1.44	0.57	0.34	2.43	1.82	1.94	1.46
26	36 maintain AI/Robotics systems (e.g., update database, fix hardware and software).	2.43	1.37	1.37	0.77	2.21	1.02	0.56	0.26	2.61	1.77	2.00	1.35
27	8 give oral presentations on AI/Robotics at symposia, conferences, and workshops.	2.18	1.06	1.39	0.68	1.94	0.64	0.57	0.19	2.31	1.54	1.85	1.24
27	29 develop tools and methodologies to assist in testing AI/Robotics systems.	2.22	1.29	1.31	0.76	2.00	0.92	0.45	0.21	2.38	1.70	1.93	1.38
29	14 identify, evaluate, and recommend outside providers for AI/Robotics-related services.	2.22	1.38	1.23	0.76	2.21	1.13	0.57	0.29	2.22	1.67	1.74	1.31
30	33 identify AI/Robotics re-use opportunities.	2.03	1.21	1.26	0.75	1.50	0.71	0.33	0.16	2.41	1.77	1.94	1.42
31	31 develop knowledge representations.	2.15	1.11	1.27	0.66	1.66	0.77	0.44	0.21	2.61	1.50	2.04	1.17
32	6 advise academia, government, and industry on AI/Robotics topics.	2.30	1.23	1.07	0.57	2.57	1.33	0.58	0.30	2.00	1.11	1.59	0.88
33	5 perform on-the-job training for co-workers in the use of AI/Robotics tools and techniques.	2.15	1.12	1.13	0.59	2.15	1.02	0.57	0.27	2.15	1.23	1.67	0.96
34	3 develop/update formal AI/Robotics training courses (e.g., classroom training).	2.00	0.31	1.34	0.21	1.83	0.20	0.53	0.06	2.10	0.44	1.83	0.38
35	2 develop/update AI/Robotics workshops and seminars.	2.00	0.56	1.12	0.32	2.14	0.55	0.61	0.16	1.87	0.58	1.60	0.50
36	1 identify training needs and sources for AI/Robotics personnel.	1.93	0.79	1.08	0.45	1.79	0.63	0.45	0.16	2.04	0.98	1.61	0.77
36	4 teach AI/Robotics courses.	2.00	0.27	1.20	0.16	1.86	0.24	0.51	0.07	2.14	0.31	1.89	0.28

Notes. Lower rank values reflect more important tasks. The final rank is the mean of all four ranks in the row. In the *ignore zero* columns, the mean score was set to missing for a task if the respondent rated it as being *not performed.* In the *include zero* columns, the mean score was set to zero for a task if the respondent rated it as being *not performed.* For the weighted columns, the ratings were multiplied by the proportion of time the respondent spent in AI/Robotics activities.

Table A-2. Job Analysis Survey: Ranks of Tasks According to Mean Importance

Final Rank	Task	All Respondents (n = 121) unweighted ignore zero	All Respondents (n = 121) unweighted include zero	All Respondents (n = 121) weighted ignore zero	All Respondents (n = 121) weighted include zero	Respondents with AI/Robotics < 50% (n = 65) unweighted ignore zero	Respondents with AI/Robotics < 50% (n = 65) unweighted include zero	Respondents with AI/Robotics < 50% (n = 65) weighted ignore zero	Respondents with AI/Robotics < 50% (n = 65) weighted include zero	Respondents with AI/Robotics > 50% (n = 56) unweighted ignore zero	Respondents with AI/Robotics > 50% (n = 56) unweighted include zero	Respondents with AI/Robotics > 50% (n = 56) weighted ignore zero	Respondents with AI/Robotics > 50% (n = 56) weighted include zero
1	11 identify and assess opportunities to apply AI/Robotics to improve processes and systems.	4	1	5	1	3	1	2	1	4	2	3	2
2	16 perform overall project management (e.g., monitor budgets and timelines) of funded AI/Robotics efforts.	1	5	1	5	2	8	3	8	1	4	1	4
3	17 manage daily functions of funded AI/Robotics efforts.	3	5	2	3	9	16	8	17	2	3	2	3
4	10 read research articles, reports, and other sources (e.g., internet messages) to keep abreast of current and emerging AI/Robotics practices and technologies.	5	2	7	2	12	2	9	2	3	1	4	1
4	21 oversee contractors performing AI/Robotics work.	2	4	4	6	1	3	1	3	6	6	6	8
6	7 seek and maintain liaisons with academia/industry/government to keep abreast of current and emerging AI/Robotics practices and technologies.	7	3	10	4	8	4	7	4	7	5	7	5
7	28 build systems (e.g., computer programs) using AI/Robotics principles and techniques.	6	18	3	13	13	21	24	25	5	10	5	10
8	24 select available knowledge sources (e.g., subject matter experts, data).	8	7	16	10	11	7	21	9	9	9	11	9
9	27 assist users in refining AI/Robotics system requirements.	13	12	9	8	26	19	32	24	11	6	9	6
10	12 evaluate proposals and plans for AI/Robotics projects and programs.	10	10	18	11	4	5	5	6	23	14	18	13
11	12 develop written or oral proposals to obtain funds for of AI/Robotics projects and programs.	11	17	11	17	17	18	19	16	8	17	8	16
11	24 develop AI/Robotics system specifications (e.g., for environment, software, hardware, and interface).	12	13	17	14	15	14	11	12	14	13	17	15
13	23 conduct basic research in AI/Robotics.	9	22	8	24	6	24	12	27	13	23	12	23
14	15 identify, evaluate, and recommend procurement of specific hardware and software tools.	18	10	24	12	14	9	23	11	21	11	22	11
15	30 evaluate AI/Robotics software, hardware, and tools.	25	8	25	7	24	10	25	7	24	6	25	7
15	31 integrate AI/Robotics components into systems.	16	14	20	15	15	14	10	10	19	15	21	17
17	18 write technical papers, reports, and journal articles on AI/Robotics efforts.	17	23	6	21	17	28	4	21	17	22	13	21
18	26 perform knowledge engineering (e.g., interviewing subject matter experts, evaluating data).	14	16	22	19	7	10	14	13	25	20	24	20

table continues . . .

Final Rank	Task	All Respondents (n = 121)				Respondents with AI/Robotics < 50% (n = 65)				Respondents with AI/Robotics > 50% (n = 56)			
		unweighted		weighted		unweighted		weighted		unweighted		weighted	
		ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero
19	9 attend courses, symposia, seminars, and conferences to keep abreast of current and emerging AI/Robotics practices and technologies.	26	9	29	9	22	6	22	5	26	12	26	12
19	34 test and evaluate AI/Robotics components and/or systems.	24	20	13	16	29	23	28	20	16	15	14	14
21	37 upgrade AI/Robotics systems (e.g., add new capabilities).	19	21	15	20	23	20	30	22	12	18	16	19
22	22 oversee staff performing AI/Robotics work.	15	25	14	25	28	25	31	28	10	25	10	25
23	19 give briefings on AI/Robotics-related efforts (e.g., to higher command levels).	22	15	26	18	17	13	27	15	22	18	20	18
24	35 transition AI/Robotics system operation knowledge from design team to end user.	23	24	12	23	30	29	36	31	15	21	15	22
25	20 develop and revise statements of work related to AI/Robotics.	20	19	28	22	10	12	16	14	27	24	27	24
26	36 maintain AI/Robotics systems (e.g., update database, fix hardware and software).	21	27	21	26	21	27	20	26	20	26	23	28
27	8 give oral presentations on AI/Robotics at symposia, conferences, and workshops.	30	33	19	30	32	33	15	32	30	30	31	30
27	29 develop tools and methodologies to assist in testing AI/Robotics systems.	29	28	27	28	30	29	34	29	29	28	29	27
29	14 identify, evaluate, and recommend outside providers for AI/Robotics-related services.	28	26	32	27	20	22	17	19	31	29	33	29
30	33 identify AI/Robotics re-use opportunities.	33	30	31	29	37	32	37	34	28	26	28	26
31	31 develop knowledge representations.	32	32	30	31	36	31	35	30	18	31	19	31
32	6 advise academia, government, and industry on AI/Robotics topics.	27	29	37	33	4	17	13	18	36	33	37	33
33	5 perform on-the-job training for co-workers in the use of AI/Robotics tools and techniques.	31	31	34	32	25	26	18	23	32	32	34	32
34	3 develop/update formal AI/Robotics training courses (e.g., classroom training).	34	36	23	36	34	37	26	37	34	36	32	36
35	2 develop/update AI/Robotics workshops and seminars.	34	35	35	35	26	35	6	35	37	35	36	35
36	1 identify training needs and sources for AI/Robotics personnel.	37	34	36	34	35	34	33	33	35	34	35	34
36	4 teach AI/Robotics courses.	34	37	33	37	33	36	29	36	33	37	30	37

Notes. Lower rank values reflect more important tasks. The final rank is the mean of all four ranks in the row. In the *ignore zero* columns, the mean score was set to missing for a task if the respondent rated it as being *not performed*. In the *include zero* columns, the mean score was set to zero for a task if the respondent rated it as being *not performed*. For the weighted columns, the ratings were multiplied by the proportion of time the respondent spent in AI/Robotics activities.

Table A-3. Job Analysis Survey: Mean Competency Importance

Final Rank	Knowledge	All Respondents (n = 121) unweighted ignore zero	include zero	weighted ignore zero	include zero	Respondents with AI/Robotics < 50% (n = 65) unweighted ignore zero	include zero	weighted ignore zero	include zero	Respondents with AI/Robotics > 50% (n = 56) unweighted ignore zero	include zero	weighted ignore zero	include zero
1	47 modeling	3.21	2.50	1.63	1.27	2.98	2.26	0.66	0.50	3.45	2.76	2.68	2.14
2	46 simulation	3.19	2.40	1.63	1.23	3.09	2.23	0.68	0.49	3.30	2.58	2.61	2.04
3	9 knowledge bases	3.11	2.22	1.67	1.20	3.00	1.84	0.69	0.42	3.20	2.67	2.50	2.08
4	1 expert systems	3.10	2.28	1.63	1.20	2.86	1.90	0.61	0.41	3.34	2.72	2.60	2.12
5	44 conceptual modeling of problems and solutions	3.02	2.14	1.64	1.16	2.87	1.79	0.65	0.40	3.16	2.52	2.50	2.00
6	12 methodologies for integrating AI with modeling, database, optimization, mathematical, statistical, or other computer programs	3.20	2.03	1.72	1.09	3.00	1.67	0.71	0.39	3.38	2.44	2.63	1.90
7	34 high-level computer programming languages (e.g., C, LISP, Ada)	3.05	1.97	1.77	1.15	2.78	1.48	0.65	0.35	2.36	2.50	2.60	2.00
8	10 the basic principles of AI theory	3.01	2.16	1.57	1.13	3.10	1.92	0.75	0.47	2.93	2.44	2.28	1.90
9	25 knowledge respesentation techniques and principles	2.97	1.96	1.68	1.11	2.65	1.45	0.58	0.32	3.23	2.53	2.55	2.00
10	33 principles of object-oriented programming	2.83	2.03	1.61	1.16	2.58	1.58	0.60	0.37	3.04	2.55	2.16	2.05
11	41 sensors	3.02	2.11	1.50	1.04	2.89	2.02	0.65	0.45	3.18	2.21	2.45	1.71
12	35 knowledge representation tools and architectures (e.g., relational databases)	2.90	2.03	1.56	1.09	2.86	1.71	0.64	0.38	2.93	2.40	2.32	1.89
12	50 applied mathematics (e.g., calculus, algebra) and statistics	3.00	2.35	1.40	1.10	3.21	2.48	0.72	0.56	2.77	2.20	2.17	1.72
14	26 software engineering	2.82	2.06	1.53	1.11	2.67	1.73	0.61	0.40	2.96	2.42	2.32	1.90
15	13 knowledge engineering	2.90	1.98	1.55	1.06	2.72	1.68	0.60	0.37	3.07	2.33	2.45	1.86
16	40 real time programming	2.87	1.66	1.69	0.98	2.62	1.11	0.61	0.26	3.02	2.25	2.38	1.77
17	32 computer system software component interfaces	2.61	2.05	1.41	1.11	2.52	1.79	0.62	0.44	2.69	2.35	2.12	1.85
18	24 distributed databases	2.78	1.62	1.64	0.95	2.50	1.15	0.58	0.27	2.97	2.15	2.39	1.73
19	48 research design methods	2.93	1.79	1.45	0.89	3.00	1.74	0.68	0.39	2.86	1.85	2.24	1.45
20	20 search strategies	2.71	1.78	1.52	0.99	2.58	1.39	0.58	0.32	2.81	2.20	2.23	1.74
21	21 the basic principles of robotics	2.85	1.67	1.44	0.85	2.69	1.59	0.63	0.37	3.03	1.76	2.36	1.37
22	49 measurement	2.88	1.78	1.35	0.84	2.90	1.85	0.64	0.41	2.85	1.71	2.19	1.31
23	17 embedded systems	2.84	1.49	1.50	0.79	2.89	1.26	0.67	0.29	2.79	1.76	2.15	1.35
24	30 computer operating systems	2.52	2.09	1.29	1.07	2.55	2.02	0.61	0.49	2.48	2.16	1.98	1.73
24	31 computer system hardware component interfaces	2.63	1.89	1.35	0.97	2.64	1.79	0.63	0.43	2.62	2.00	2.07	1.58

table continues . . .

Final Rank	Knowledge	All Respondents (n = 121)				Respondents with AI/Robotics < 50% (n = 65)				Respondents with AI/Robotics > 50% (n = 56)			
		unweighted		weighted		unweighted		weighted		unweighted		weighted	
		ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero
26	51 optimization techniques	2.66	1.96	1.30	0.96	2.76	1.87	0.59	0.40	2.57	2.05	1.98	1.59
27	42 image processing software and hardware	2.72	1.53	1.38	0.77	2.74	1.39	0.63	0.32	2.71	1.67	2.07	1.28
28	18 sensor fusion	2.73	1.47	1.37	0.74	2.56	1.32	0.60	0.31	2.90	1.64	2.19	1.24
29	2 neural networks	2.65	1.54	1.35	0.78	2.60	1.44	0.57	0.31	2.70	1.65	2.18	1.33
30	29 computer system architectures	2.44	1.77	1.32	0.95	2.54	1.54	0.59	0.36	2.36	2.02	1.89	1.61
31	27 computer vision	2.69	1.24	1.47	0.68	2.67	1.05	0.62	0.26	2.70	1.45	2.15	1.15
31	43 data acquisition hardware and software	2.54	1.66	1.29	0.84	2.49	1.59	0.60	0.38	2.59	1.75	2.03	1.36
33	7 heuristic algorithms	2.47	1.36	1.41	0.78	2.17	1.00	0.48	0.22	2.71	1.79	2.19	1.44
34	45 parallel processing techniques	2.63	1.28	1.46	0.71	2.50	1.07	0.56	0.24	2.74	1.52	2.22	1.23
35	8 fuzzy logic	2.58	1.46	1.30	0.74	2.56	1.30	0.58	0.29	2.61	1.65	2.01	1.27
36	22 robot navigation	2.68	1.19	1.38	0.61	2.59	1.15	0.63	0.28	2.78	1.23	2.25	1.00
37	16 control theory	2.57	1.55	1.23	0.74	2.54	1.59	0.61	0.38	2.61	1.50	2.02	1.16
38	38 the application of commercial AI tools (e.g., preprocessing tools, AI shells)	2.48	1.34	1.34	0.73	2.50	1.13	0.60	0.27	2.46	1.59	1.92	1.25
39	11 AI shells	2.47	1.46	1.25	0.74	2.59	1.36	0.57	0.30	2.36	1.57	1.85	1.23
40	5 agent architictures	2.38	0.97	1.49	0.61	2.00	0.62	0.47	0.15	2.64	1.37	2.18	1.13
41	23 hybrid systems	2.44	1.32	1.33	0.72	2.43	1.10	0.55	0.25	2.46	1.56	1.96	1.24
42	3 path planning	2.46	1.41	1.28	0.73	2.45	1.29	0.57	0.03	2.47	1.56	1.97	1.24
43	28 natural language	2.30	0.99	1.38	0.59	2.20	0.72	0.53	0.17	2.37	1.29	1.94	1.06
44	4 blackboard theory	2.23	1.01	1.30	0.59	1.82	0.69	0.04	0.14	2.55	1.37	2.03	1.09
45	6 genetic algorithms	2.38	1.06	1.25	0.58	2.46	0.94	0.55	0.21	2.32	1.20	1.86	0.96
46	14 first-order logic	2.22	1.13	1.12	0.57	2.35	1.14	0.54	0.26	2.07	1.13	1.72	0.95
47	19 message fusion	2.30	0.93	1.18	0.48	2.35	0.89	0.57	0.21	2.26	0.98	1.80	0.78
48	37 case-based reasoning software	2.10	0.94	1.14	0.51	2.04	0.79	0.46	0.18	2.14	1.11	1.72	0.89
49	15 frame-based systems	2.17	0.90	1.13	0.47	2.19	0.73	0.44	0.15	2.15	1.09	1.67	0.85
50	36 expert system blackboard software	2.13	0.84	1.16	0.46	1.90	0.65	0.37	0.13	2.32	1.05	1.82	0.83
51	39 machine translation of languages	2.22	0.77	1.11	0.38	2.29	0.79	0.56	0.19	2.16	0.75	1.71	0.59

Notes. Lower rank values reflect more important knowledges. The *final rank* is based on the mean of the four ranks for *all respondents* (i.e., ranks for unweighted include zero, unweighted ignore zero, weighted include zero, weighted ignore zero). In the *ignore zero* columns, the mean score was set to missing for a knowledge if the respondent rated it as being *not required*. In the *include zero* columns, the mean score was set to zero for a knowledge if the respondent rated it as being *not required*. For the weighted columns, the ratings were multiplied by the proportion of time the respondent spent in AI/Robotics activities.

Table A-4. Job Analysis Survey: Ranks of Competencies According to Mean Importance

		All Respondents (n = 121)				Respondents with AI/Robotics < 50% (n = 65)				Respondents with AI/Robotics > 50% (n = 56)			
		unweighted		weighted		unweighted		weighted		unweighted		weighted	
Final Rank	Knowledge	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero
1	47 modeling	1	1	8	1	7	2	8	2	1	1	1	1
2	46 simulation	3	2	8	2	3	3	5	3	4	4	3	5
3	9 knowledge bases	4	5	5	3	4	10	4	9	6	3	7	3
4	1 expert systems	5	4	8	3	12	7	20	10	3	2	4	2
5	44 conceptual modeling of problems and solutions	7	7	6	5	11	11	9	12	8	7	7	6
6	12 methodologies for integrating AI with modeling, database, optimization, mathematical, statistical, or other computer programs	2	12	2	13	4	18	3	15	2	9	2	9
7	34 high-level computer programming languages (e.g., C, LISP, Ada)	6	16	1	7	14	24	9	24	42	8	4	6
8	10 the basic principles of AI theory	9	6	12	8	2	6	1	5	15	9	16	9
9	25 knowledge respesentation techniques and principles	11	17	4	9	21	25	32	25	5	6	6	6
10	33 principles of object-oriented programming	19	12	11	5	27	22	25	20	10	5	27	4
11	41 sensors	7	8	17	17	9	4	9	6	7	16	9	20
12	35 knowledge representation tools and architectures (e.g., relational databases)	13	12	13	13	12	16	12	17	15	12	14	12
12	50 applied mathematics (e.g., calculus, algebra) and statistics	10	3	26	12	1	1	2	1	23	17	26	19
14	26 software engineering	20	10	15	9	19	15	20	12	14	11	14	9
15	13 knowledge engineering	13	15	14	16	17	17	25	20	9	14	9	13
16	40 real time programming	16	25	3	19	23	38	20	36	12	15	12	15
17	32 computer system software component interfaces	31	11	24	9	34	11	18	7	29	13	30	14
18	24 distributed databases	21	27	6	22	35	34	32	34	13	20	11	17
19	48 research design methods	12	20	22	24	4	14	5	15	18	24	18	24
20	20 search strategies	24	21	16	18	27	27	32	25	20	17	19	16
21	21 the basic principles of robotics	17	24	23	25	18	19	14	20	11	26	13	26
22	49 measurement	15	21	31	26	8	9	12	10	19	29	21	30
23	17 embedded systems	18	31	17	28	9	33	7	31	21	26	28	28
24	30 computer operating systems	35	9	40	15	31	4	20	3	37	19	37	17
24	31 computer system hardware component interfaces	29	19	31	20	22	11	14	8	31	23	31	23

table continues . . .

Final Rank	Knowledge	All Respondents (n = 121)				Respondents with AI/Robotics < 50% (n = 65)				Respondents with AI/Robotics > 50% (n = 56)			
		unweighted		weighted		unweighted		weighted		unweighted		weighted	
		ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero	ignore zero	include zero
26	51 optimization techniques	27	17	37	21	15	8	30	12	35	21	37	22
27	42 image processing software and hardware	23	30	27	31	16	27	14	25	25	30	31	31
28	18 sensor fusion	22	32	30	32	29	30	25	28	17	33	21	34
29	2 neural networks	28	29	31	29	24	26	36	28	27	31	24	29
30	29 computer system architectures	40	23	36	22	32	23	30	23	42	22	43	21
31	27 computer vision	25	40	20	40	19	41	18	36	27	40	28	40
31	43 data acquisition hardware and software	34	25	40	26	38	19	25	17	34	28	33	27
33	7 heuristic algorithms	37	36	24	29	47	42	46	41	25	25	21	25
34	45 parallel processing techniques	29	39	21	39	35	40	40	40	24	38	20	37
35	8 fuzzy logic	32	33	37	32	29	31	32	31	32	31	36	32
36	22 robot navigation	26	41	27	41	25	34	14	33	22	44	17	44
37	16 control theory	33	28	45	32	32	19	20	17	32	39	35	39
38	38 the application of commercial AI tools (e.g., preprocessing tools, AI shells)	36	37	34	36	35	37	25	34	39	34	42	33
39	11 AI shells	37	33	43	32	25	29	36	30	42	35	45	37
40	5 agent architictures	42	46	19	41	49	51	47	47	30	41	24	41
41	23 hybrid systems	40	38	35	38	41	39	42	39	39	36	40	34
42	3 path planning	39	35	42	36	40	32	36	51	38	36	39	34
43	28 natural language	44	45	27	43	45	48	45	46	41	43	41	43
44	4 blackboard theory	46	44	37	43	51	49	51	49	36	41	33	42
45	6 genetic algorithms	42	43	43	45	39	43	42	42	45	45	44	45
46	14 first-order logic	47	42	50	46	42	36	44	36	51	46	48	46
47	19 message fusion	44	48	46	48	42	44	36	42	47	50	47	50
48	37 case-based reasoning software	51	47	48	47	48	45	48	45	50	47	48	47
49	15 frame-based systems	49	49	49	49	46	47	49	47	49	48	51	48
50	36 expert system blackboard software	50	50	47	50	50	50	50	50	45	49	46	49
51	39 machine translation of languages	47	51	51	51	44	45	40	44	48	51	50	51

Notes. Lower rank values reflect more important knowledges. The *final rank* is based on the mean of the four ranks for *all respondents* (i.e., ranks for unweighted include zero, unweighted ignore zero, weighted include zero, weighted ignore zero). In the *ignore zero* columns, the mean score was set to missing for a knowledge if the respondent rated it as being *not required*. In the *include zero* columns, the mean score was set to zero for a knowledge if the respondent rated it as being *not required*. For the weighted columns, the ratings were multiplied by the proportion of time the respondent spent in AI/Robotics activities.

APPENDIX B. Data Call Questionnaire

Survey for Army Civilians Working in Artificial Intelligence or Robotics

Please complete this questionnaire if you are an Army civilian who develops and/or manages artificial intelligence or robotics projects.

Supervisors: Please complete a survey for each unencumbered (vacant) artificial intelligence/robotics position in your office. Print "unencumbered" in the "Name:" block below for an unencumbered position.

PRIVACY ACT STATEMENT

Authority: 5 USC SECTION 301, Executive Order 9397, AR 340-21, and AR 611-3.

Principal Purpose: To determine which positions have activities related to the development of artificial intelligence or robotics.

Routine Uses: Names or other individual identifiers of persons completing this survey will be treated confidentially. Data will be used to identify persons working in artificial intelligence or robotics.

Disclosure: Completion of this survey is voluntary. However, the quality of the Army civilian Artificial Intelligence Specialty Program is dependent upon employee cooperation in completing this questionnaire.

Complete the following information about yourself. Please print.

Name:
(print "unencumbered" if position is currently vacant)

Major Army Command:

Major Subordinate Command:

Agency/Activity:

Mailing Address:
(complete address: include office symbol and zip code)

Career Program:

Grade:

Job Series:

For the purposes of this survey, the definition of **artificial intelligence is:**

AI is a branch of science dedicated to the development of computational programs that exhibit intelligent behaviors and actions such as problem solving, learning, and understanding language. AI techniques imitate human thought, actions, or decision making processes or produce results similar to these processes.

For the purposes of this survey, the definition of **robotics is:**

Robotics is a branch of science dedicated to the study, development, and application of mechanical/electrical systems that perform tasks involving sensing, computation, and action. These mechanical/electrical systems can be teleoperated (human interface is used for control), autonomous (independent of real-time human control), or semi-autonomous. Military applications of Army robots generally fall into two categories: tactical and industrial.

1. **Given the above definitions,** what percentage of the time on your job involves tasks related to artificial intelligence and/or robotics? Circle the appropriate percentage below.

none < 3% 3-5 % 6-25 % 26-50 % 51-74 % 75-94 % 95-97 % >97%

2. List any areas of artificial intelligence or robotics in which you are involved that are **not** covered by the definition above.

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- End of Questionnaire -

APPENDIX C. Job Analysis Questionnaire

DEPARTMENT OF THE ARMY
OFFICE OF THE SECRETARY OF THE ARMY
107 ARMY PENTAGON
WASHINGTON DC 20310-0107

Office, Director of Information Systems for Command, Control, Communications, & Computers

S: 10 July 1996

17 June 1996

SAIS-IDD

MEMORANDUM FOR DEPARTMENT OF THE ARMY CIVILIAN ARTIFICIAL INTELLIGENCE PROFESSIONALS

SUBJECT: Army Civilian Artificial Intelligence (AI) Job Analysis Survey

1. Your name was identified through an Army-wide population survey as an Army civilian currently performing duties in AI and/or robotics. You are requested to complete and return the attached "Job Analysis Inventory for Civilians Working in Artificial Intelligence and Robotics" (enclosure 1).

2. The "Job Analysis Inventory for Civilians Working in Artificial Intelligence and Robotics" is a critical part of an Army-wide effort to create a one-of-a-kind civilian specialty program for Army civilians. In order to fully exploit the potential of AI/robotics, it is imperative for the Army to identify, train, and manage a talent pool of individuals with AI/robotics skills. The Army has a program to do this with its military personnel -- the AI Civilian Specialty Program will allow the Army to do the same with its civilian personnel.

3. AI is a unique set of skills not restricted to a given civilian career program (CP) or occupational series. As such, this program will involve participation by the Army CPs and use their CP training and referral systems. It will identify and provide AI professional development and training opportunities, establish an AI Specialty Advisory Council, and provide a voluntary certification program for Army civilians with AI skills.

4. Instructions for completing the survey are contained within the survey. If you have any questions about completing the survey, please contact Dr. Gordon Waugh at the Human Resources Research Organization (HumRRO), (703) 706-5666. Completed surveys must be returned in their sealed envelopes NLT 10 July 1996. Dr. Waugh's address is:

Dr. Gordon Waugh
Human Resources Research Organization
66 Canal Center Plaza, Suite 400
Alexandria, VA 22314

5. The ODISC4 points of contact are Mrs. Mary Campbell at (703) 695-9304/DSN 225-9304 or MAJ Bill Atkinson at DSN 224-6904/(703) 614-6904.

Encl

OTTO J. GUENTHER
Lieutenant General, GS
Director

Job Analysis Inventory for Army Civilians Working in Artificial Intelligence or Robotics

PRIVACY ACT STATEMENT

Authority: 5 USC SECTION 301, Executive Order 9397, AR 340-21, and AR 611-3.

Principal Purpose: To determine the tasks performed and knowledge required by Army civilians working in Artificial Intelligence and Robotics.

Routine Uses: Names or other individual identifiers of persons completing this survey will be treated confidentially. Data will be used to determine the similarities and differences in tasks performed and knowledge required among Army civilians working in Artificial Intelligence and Robotics. This information will aid in creating a voluntary certification program for Army civilians working in Artificial Intelligence and Robotics.

Disclosure: Completion of this survey is voluntary. However, the quality of the Army civilian Artificial Intelligence and Robotics Specialty Program is dependent upon employee cooperation in completing this questionnaire.

Organization of Inventory

This inventory is divided into three sections:

Section I - **Background Information** requests information about your position and your job-related background which will help to ensure that a representative group of job incumbents has been surveyed and allow examination of differences in job requirements across various types of AI/Robotics positions.

Section II - **Job Tasks** contains a list of tasks related to AI/Robotics. You will be asked to read each task statement and indicate how much the task is a part of *your* job.

Section III - **Knowledges** contains a list of knowledge areas related to AI/Robotics. You will be asked to read each knowledge statement and indicate how important it is in *your* job and the level of the knowledge required to perform your job.

Section IV - **Related Training** requests that you list the courses that have helped you prepare for your AI/Robotics work.

General Instructions - *Read Carefully!*

This is *not* a test — it is a survey. Your responses to this survey will be used to (a) provide information about the tasks performed in AI/Robotics jobs and the knowledge required to perform these tasks, (b) help create a voluntary certification program for Army civilians working in AI/Robotics, and (c) help determine the criteria and procedures for the training and recruitment of AI/Robotics personnel.

This survey is confidential. It will not be used to evaluate you in any way.

Do not be concerned if there are many tasks and/or knowledges that are irrelevant to your position. This inventory was designed to cover all positions in AI/Robotics; thus, it is unlikely that every task or knowledge statement will apply to your current position.

- Respond only in terms of your current position, not your previous positions or those of your subordinates.

- Think of your job as you actually perform it, not as it is described in your position description or as you think it should be performed.

- If you have any questions, please contact the person at your location responsible for the administration of this inventory or call Dr. Gordon Waugh (703) 706-5666 at the Human Resources Research Organization (HumRRO) in Alexandria, Virginia.

- When you have completed the inventory, ***place it in the stamped pre-addressed envelope provided, seal it, and mail it.*** The envelope provided is addressed to:

  Gordon Waugh
  HumRRO
  66 Canal Center Plaza, Suite 400
  Alexandria, VA 22314

For the purposes of this survey, the definition of **artificial intelligence is:**

> *...a branch of science dedicated to the development of computational programs that exhibit intelligent behaviors and actions such as problem solving, learning, and understanding language. AI techniques imitate human thought, actions, or decision making processes or produce results similar to these processes.*

For the purposes of this survey, the definition of **robotics** is:

> *...a branch of science dedicated to the study, development, and application of mechanical/electrical systems that perform tasks involving sensing, computation, and action. These mechanical/electrical systems can be teleoperated (human interface is used for control), autonomous (independent of real-time human control), or semi-autonomous. Military applications of Army robots generally fall into two categories: tactical and industrial.*

Section I. Background

NOTE:
If you are NOT an Army civilian working in artificial intelligence or robotics as defined below, mark here and return you survey uncompleted.

Marking Instructions

CORRECT MARK

INCORRECT MARKS

- Use a No. 2 pencil.
- Fill in the circle completely.
- Erase cleanly any marks you wish to change.
- Do not make any stray marks on this form.

I-1

Name: ______________________________

1. What percentage of the time on your job involves tasks related to artificial intelligence and/or robotics?

none
<5%
6–9
10–19
20–29
30–39
40–49
50–59
60–69
70–79
80–89
90–95
>95

2. What is your present pay grade?

GS-7
GS-9
GS-11
GS-12
GS-13
GS-14
GS-15
GM-13
GM-14
GM-15
SES
ST
Other (please specify) ______________

3. What is your Career Program?

11 - Comptroller
13 - Supply Management
16 - Engineers & Scientists (non-construction)
18 - Engineers & Scientists (construction)
24 - Transportation Management
26 - Manpower and Force Management
34 - IMA
Other (please specify) :

____

____

4. What job series are you in?

180 - Psychology
301 - Information Systems Manager
334 - Computer Specialist
403 - Microbiology
801 - General Engineering
806 - Materials Engineering
830 - Mechanical Engineering
850 - Electrical Engineering
854 - Computer Engineering
855 - Electronics Engineering
856 - Electronics Technician
858 - Biomedical Engineering
861 - Aerospace Engineering
893 - Chemical Engineering
896 - Industrial Engineering
1310 - Physics
1320 - Metallurgy
1321 - Chemistry
1515 - Operationsd Research
1529 - Mathematics and Statistics
1550 - Computer Science
2101 - Transportation Specialist
2130 - Traffic Management
Other (please specify)

____

____

Section I. Background

5. **Is HQDA (Headquarters, Department of the Army) your Army major command (MACOM)?**

No --> **SKIP TO QUESTION 7**
Yes

6. **What is your HQDA activity?**

Concepts Analysis Agency (CAA)
Deputy Chief of Staff for Logistics (ODCSLOG)
Deputy Chief of Staff for Personnel (ODCSPER)
Office of the Director of Information Systems for C4 (ODISC4)
Operational Tert and Evaluation Command (OPTEC)
Total Army Personnel Command
Other (please specify): ____________

SKIP TO QUESTION 9

7. **What is your present Army major command (MACOM)?**

Criminal Investigation Command (CIDC)
Military District of Washington (MDW)
Military Traffic Management Command (MTMC)
OCONUS: Command = ____________
US Army Corps of Engineers (USACE)
US Army Forces Command (FORSCOM)
US Army Information Systems Command (ISC)
US Army Intelligence and Security Command (INSCOM)
US Army Materiel Command (AMC)
US Army Medical Command (MEDCOM)
US Army Training and Doctrine Command (TRADOC)
Other (please specify): ____________

8. **What is your present major subordinate command?**

US Army Aviation and Troop Command (ATCOM)
US Army Chemical and Biological Defence Command (CBDCOM)
US Army Combined Arms Center (CAC)
US Army Combined Arms Support Center (CASCOM)
US Army Communications-Electronics Command (CECOM)
USAMC Executive Director for Conventional Ammunition (EDCA)
USA Industrial Engineering Activity (IEA)
US Army Industrial Operations Command (IOC)
US Army Information Systems Software Center (ISSC)
US Army Information System s Engineering Command (ISEC)
USAMC Logistics Support Activity (LOGSA)
US Army Missile Command (MICOM)
US Army Research Laboratory (ARL)
US Army Security Assistance Command (USASAC)
US Army Simulation, Training, and Instrumentation Command (STRICOM)
US Army Soldier Systems Command (SSCOM)
US Army Test and Evaluation Command (TECOM)
I Corps
III Corps
V Corps
XVIII Airborne Corps
Other (please specify): ____________

9. **Which of the following sources of training/education have you used to learn about AI/Robotics? (Mark all that apply)**

Reading AI/Robotics literature
On-the-job training
Attending conferences
College courses
Private providers of training (e.g., NeuralWare)
Government providers of training: Military (e.g., Army Logistics Management College)
Government providers of training: Non-military (e.g., FBI)

Section I. Background

10. What is your highest level of education?

High school diploma or equivalent
Some college
Associate's degree (2-year),
specify area of study ______________________

Bachelor's degree (4-year),
specify area of study ______________________

Some graduate school,
specify area of study ______________________

Master's degree,
specify area of study ______________________

Doctoral degree,
specify area of study ______________________

11. How long have you been in your present position?

Less than 6 months
6 months to less than 1 year
1 year to less than 3 years
3 years to less than 5 years
5 years to less than 10 years
10 or more years

12. How long have you used AI/Robotics in your present position?

Less than 6 months
6 months to less than 1 year
1 year to less than 3 years
3 years to less than 5 years
5 years to less than 10 years
10 or more years

13. What level supervisor are you?

Not a supervisor
Team leader (not in an officially designated supervisory position)
First level supervisor
Second level supervisor
Above second level supervisor

Section II.
Job Tasks

This section contains a list of job tasks related to AI/Robotics that was developed through extensive consultation with personnel in AI/Robotics. You will note that the range of tasks is very broad and there may be many tasks that are not relevant to your current position.

To familiarize yourself with the list, you should first read all of the task statements once through. Next, read each task statement in turn, and rate how much the task is a part of the AI/Robotics portion of your job using the following scale:

A Part of the Job

0 - **Not performed**
1 - **Much less** a part of the job than most other AI/Robotics tasks
2 - **Somewhat less** a part of the job than most other AI/Robotics tasks
3 - A part of the job **about the same** amount as most other AI/Robotics tasks
4 - **Somewhat more** a part of the job than than most other AI/Robotics tasks
5 - **Much more** a part of the job than than most other AI/Robotics tasks

Note that you are rating each task relative to other AI/Robotics tasks that you perform; thus rating a task "1" does not mean that it is not a part of the job, just that it is not as much a part of the job as other AI/Robotics tasks for which you are responsible.

In your ratings of the extent to which each task is a part of the job, consider *how often* you perform the task, the *amount of time* you spend performing the task, and any other factors you think are related to how much a task is a part of the job. Obviously, the tasks you do from day to day vary with the projects on which you work. Therefore, think about your job over time when making these ratings.

Section II. Job Tasks

A Part of the Job:

0 - Not performed.
1 - Much less a part of the job than most other AI/Robotics tasks
2 - Somewhat less a part of the job than most other AI/Robotics tasks
3 - A part of the job about the same amount as most other AI/Robotocs tasks
4 - Somewhat more a part of the job than most other AI/Robotics tasks
5 - Much more a part of the job than most other AI/Robotics tasks

	A PART OF THE JOB: Not Performed 0 / Much Less 1 / Somewhat Less 2 / About the Same 3 / Somewhat More 4 / Much More 5
1. Identify training needs and sources for AI/robotics personnel.	
2. Develop/update AI/robotics workshops and seminars.	
3. Develop/update formal AI/robotics training courses (e.g., classroom training).	
4. Teach AI/robotics courses.	
5. Perform on-the-job training for co-workers in the use of AI/robotics tools and techniques.	
6. Advise academia, government, and industry on AI/robotics topics.	
7. Seek and maintain liaisons with academia/industry/government to keep abreast of current and emerging AI/robotics practices and technologies.	
8. Give oral presentations on AI/robotics at symposia, conferences, and workshops.	
9. Attend courses, symposia, seminars, and conferences to keep abreast of current and emerging AI/robotics practices and technologies.	
10. Read research articles, reports, and other sources (e.g., internet messages) to keep abreast of current and emerging AI/robotics practices and technologies.	
11. Identify and assess opportunities to apply AI/robotics to improve processes and systems.	
12. Develop written or oral proposals to obtain funds for AI/robotics projects and programs.	
13. Evaluate proposals and plans for AI/robotics projects and programs.	
14. Identify, evaluate, and recommend outside providers for AI/robotics-related services.	
15. Identify, evaluate, and recommend procurement of specific hardware and software tools.	
16. Perform overall project management (e.g., monitor budgets and timelines) of funded AI/robotics efforts.	
17. Manage daily functions of funded AI/robotics efforts.	
18. Write technical papers, reports, and journal articles on AI/robotics efforts.	

Section II. Job Tasks

A Part of the Job:

0 - Not performed.
1 - Much less a part of the job than most other AI/Robotics tasks
2 - Somewhat less a part of the job than most other AI/Robotics tasks
3 - A part of the job about the same amount as most other AI/Robotocs tasks
4 - Somewhat more a part of the job than most other AI/Robotics tasks
5 - Much more a part of the job than most other AI/Robotics tasks

	A PART OF THE JOB: Not Performed 0	Much Less 1	Somewhat Less 2	About the Same 3	Somewhat More 4	Much More 5
19. Give briefings on AI/robotics-related efforts (e.g., to higher command levels).						
20. Develop and revise statements of work related to AI/robotics.						
21. Oversee contractors performing AI/robotics work.						
22. Oversee staff performing AI/robotics work.						
23. Conduct basic research in AI/robotics.						
24. Select available knowledge sources (e.g., subject matter experts, data).						
25. Develop AI/robotics system specifications (e.g., for environment, software, hardware, and interface).						
26. Perform knowledge engineering (e.g., interviewing subject matter experts, evaluating data).						
27. Assist users in refining AI/robotics system requirements.						
28. Build systems (e.g., computer programs) using AI/robotics principles and techniques.						
29. Develop tools and methodologies to assist in testing AI/robotics systems.						
30. Evaluate AI/robotics software, hardware, and tools.						
31. Integrate AI/robotics components into systems.						
32. Develop knowledge representations.						
33. Identify AI/robotics re-use opportunities.						
34. Test and evaluate AI/robotics components and/or systems.						
35. Transition AI/robotics system operation knowledge from design team to end user.						
36. Maintain AI/robotics systems (e.g., update database, fix hardware and software).						
37. Upgrade AI/robotics systems (e.g., add new capabilities).						

Section II.
Job Tasks

Additional Tasks

In the space below, please list any important AI/Robotics tasks you perform that did not appear in the list.

Section III. Knowledges

This section contains a list of knowledges related to AI/Robotics that was developed through extensive consultation with personnel in AI/Robotics. You will note that the range of knowledges is very broad and there may be many knowledges that are not relevant to your current position.

To familiarize yourself with the list, you should first read all of the knowledges once through. Next, read each knowledge in turn, and rate the relevance of the knowledge to performing the AI/Robotics tasks in your job using the following scales:

Importance

0 - **Not required** at all to perform the AI/Robotics tasks on this job.
1 - **Much less** important than most other AI/Robotics-related knowledges.
2 - **Somewhat less** important than most other AI/Robotics-related knowledges.
3 - **About the same** importance as most other AI/Robotics-related knowledges.
4 - **Somewhat more** important than most other AI/Robotics-related knowledges.
5 - **Much more** important than most other AI/Robotics-related knowledges.

*If you rate the importance of a knowledge as **0** - Not Required at all to perform the job, then do **not** rate the knowledge on the **Level of Knowledge Required** scale.*

Level of Knowledge Required

1 - **General** understanding
2 - **Intermediate** level of knowledge
3 - **Advanced** level of knowledge

When making your Importance ratings, it will help to think about whether or not you could accomplish important AI/Robotics job tasks without a particular knowledge. Many knowledges might be "nice to know" but are not really necessary for successful job performance. Similarly, when making your ratings of Level of Knowledge Required, consider the minimum level of knowledge *required* for successful performance of AI/Robotics tasks, not the level that would be "nice to have."

Section III. Knowledges

Importance:

0 - **Not required** at all to perform the job.
1 - **Much less important** than most other knowledges
2 - **Somewhat less important** than most other knowledges
3 - **About the same importance** as most other knowledges
4 - **Somewhat more important** than most other knowledges
5 - **Much more important** than most other knowledges

Level of Knowledge Required:

1 - **General understanding**
2 - **Intermediate level of knowledge**
3 - **Advanced level of knowledge**

Knowledge of...	IMPORTANCE: Not Required 0	Much Less 1	Somewhat Less 2	About the Same 3	Somewhat More 4	Much More 5	LEVEL OF KNOWLEDGE REQUIRED: General 1	Intermediate 2	Advanced 3
1. expert systems.									
2. neural networks.									
3. path planning.									
4. blackboard theory.									
5. agent architectures.									
6. genetic algorithms.									
7. heuristic algorithms.									
8. fuzzy logic.									
9. knowledge bases.									
10. the basic principles of AI theory.									
11. AI shells.									
12. methodologies for integrating AI with modeling, database, optimization, mathematical, statistical, or other computer programs.									
13. knowledge engineering.									
14. first-order logic.									
15. frame-based systems.									
16. control theory.									
17. embedded systems.									
18. sensor fusion.									
19. message fusion.									

Section III. Knowledges

Importance:

0 - Not required at all to perform the job.
1 - Much less important than most other knowledges
2 - Somewhat less important than most other knowledges
3 - About the same importance as most other knowledges
4 - Somewhat more important than most other knowledges
5 - Much more important than most other knowledges

Level of Knowledge Required:

1 - General understanding
2 - Intermediate level of knowledge
3 - Advanced level of knowledge

Knowledge of...	IMPORTANCE: 0 Not Required	1 Much Less	2 Somewhat Less	3 About the Same	4 Somewhat More	5 Much More	LEVEL OF KNOWLEDGE REQUIRED: 1 General	2 Intermediate	3 Advanced
20. search strategies.									
21. the basic principles of robotics.									
22. robot navigation.									
23. hybrid systems.									
24. distributed databases.									
25. knowledge representation techniques and principles.									
26. software engineering.									
27. computer vision.									
28. natural language.									
29. computer system architectures.									
30. computer operating systems.									
31. computer system hardware component interfaces.									
32. computer system software component interfaces.									
33. principles of object-oriented programming.									
34. high-level computer programming languages (e.g., C, LISP, ADA).									
35. knowledge representation tools and architectures (e.g., relational databases).									
36. expert system blackboard software.									
37. case-based reasoning software.									
38. the application of commercial AI tools (e.g., preprocessing tools, AI shells).									
39. machine translation of languages.									

Section III. Knowledges

Importance:

0 - Not required at all to perform the job.
1 - Much less important than most other knowledges
2 - Somewhat less important than most other knowledges
3 - About the same importance as most other knowledges
4 - Somewhat more important than most other knowledges
5 - Much more important than most other knowledges

Level of Knowledge Required:

1 - General understanding
2 - Intermediate level of knowledge
3 - Advanced level of knowledge

Knowledge of...	IMPORTANCE: Not Required 0	Much Less 1	Somewhat Less 2	About the Same 3	Somewhat More 4	Much More 5	LEVEL OF KNOWLEDGE REQUIRED: General 1	Intermediate 2	Advanced 3
40. real time programming.									
41. sensors.									
42. image processing software and hardware.									
43. data acquisition hardware and software.									
44. conceptual modeling of problems and solutions.									
45. parallel processing techniques.									
46. simulation.									
47. modeling.									
48. research design methods.									
49. measurement.									
50. applied mathematics (e.g., calculus, algebra) and statistics.									
51. optimization techniques.									

Additional Knowledges

In the space below, please list any important AI/Robotics knowledges you need to perform your job that did not appear in the list.

End of Survey - Thanks for your time.

Section IV. Related Training

Please list the courses you have taken, as part of your training or education, that have helped you prepare for the AI/Robotics requirements of your job. Include only courses *directly* related to AI/Robotics. For example, you should exclude courses in math and physics unless they focus on AI or Robotics. The first line below is an example of how you should list each course.

Course Title	**Source of Course**
Introduction to AI	MIT

APPENDIX D. Task-to-Competency Linking Questionnaire

Directions for Completing the Task-to-Competency Rating Form

The left side of the *Task-to-Competency Rating Form* displays the competencies that will be used for AI/Robotics certification. The numbered columns to the right of the competencies represent the tasks that are most important for people doing AI/Robotics according to the survey results. The accompanying sheet shows the description of each task.

Your job, for each task (i.e., each numbered column), is to decide whether each competency is either *not needed, helpful,* or *essential* to performing the task properly.

Please follow these steps:

1. Print your name next to the word **Name: -->** in the top right hand corner of the *Task-to-Competency Rating Form.*

2. Read the tasks on the *Critical AI/Robotics Tasks* sheet. Note that the tasks within each group are similar, except for the last group. The tasks are grouped to make your task a little easier.

3. Read the list of competencies carefully.

4. Read the description for Task 1.

5. Read Competency 1. Decide whether Competency 1 is either *not needed, helpful,* or *essential* to performing the task properly. Write the *number* that corresponds to your decision in the square where Competency 1 and Task 1 intersect according to the scale below:

0	**not needed**	This competency is *not needed* to perform the task. Having this competency would make no difference in the performance of the task.
1	**helpful**	This competency is *helpful* in performing the task, but not essential. The task could be performed without this competency, but the task would be more difficult or time-consuming.
2	**essential**	This competency is *essential* to the performance of the task. Without this competency, you would not be able to perform the task.
?	**don't know**	If you are unfamiliar with either the task or the competency, then write a question mark in the square.

6. Read Competency 2 and repeat Step 5 above. Write the number corresponding to your rating in the square Competency 2 and Task 1 intersect. Repeat this step for each Competency.

7. Repeat Steps 5 and 6 for each task.

Critical AI/Robotics Tasks

1. Seek and maintain liaisons with academia/industry/government to keep abreast of current and emerging AI/Robotics practices and technologies.
2. Attend courses, symposia, seminars, and conferences to keep abreast of current and emerging AI/Robotics practices and technologies.
3. Read research articles, reports, and others sources (e.g., internet messages) to keep abreast of current and emerging AI/Robotics practices and technologies.
4. Perform overall project management (e.g., monitor budgets and timelines) of funded AI/Robotics efforts.
5. Manage daily functions of funded AI/robotics efforts.
6. Oversee contractors performing AI/robotics work.
7. Evaluate proposals and plans for AI/robotics projects and programs.
8. Select available knowledge sources (e.g., subject matter experts, data).
9. Perform knowledge engineering (e.g., interviewing subject matter experts, evaluating data).
10. Identify, evaluate, and recommend procurement of specific hardware and software tools.
11. Develop AI/robotics system specifications (e.g., for environment, software, hardware, and interface).
12. Evaluate AI/robotics software, hardware, and tools.
13. Identify and assess opportunities to apply AI/robotics to improve processes and systems.
14. Assist users in refining AI/robotics system requirements.
15. Build systems (e.g., computer programs) using AI/robotics principles and techniques.
16. Integrate AI/robotics components into systems.
17. Test and evaluate AI/robotics components and/or systems.

Task-to-Competency Ratings Form

Core KSAs (certificants must possess all of these) **Name ==>**

Core KSA #	KSA Description	Task Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	expert/knowledge-based systems																	
2	principles of object-oriented/symbolic/logic programming																	
3	knowledge representation																	
4	the basic principles of AI																	
5	methodologies for integrating AI with modeling, optimization, mathematical, statistical, or other computer programs																	
6	knowledge engineering																	
7	search strategies																	

0 = not needed 1 = helpful 2 = essential ? = don't know

Task-to-Competency Ratings Form

Supplemental KSAs (certificants must possess any three of these)

Suppl. KSA #	KSA Description	Task Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
8	heuristic algorithms																	
9	fuzzy logic																	
10	neural networks																	
11	the application of commercial AI tools (e.g., preprocessing tools, AI shells)																	
12	hybrid systems																	
13	path planning																	
14	blackboard systems and theory																	
15	natural language																	
16	genetic algorithms																	
17	case-based reasoning																	
18	machine learning																	
19	speech recognition/synthesis																	
20	high-level computer programming languages (e.g., C, C++, LISP, ADA)																	
21	conceptual modeling of problems and solutions																	
22	sensors																	
23	sensor fusion																	
24	the basic principles of robotics																	
25	image processing / computer vision																	
26	control theory																	
27	robot navigation																	

0 = not needed 1 = helpful 2 = essential ? = don't know

APPENDIX E. Certification Standards

Standards for the Certification of Civilians in the U.S. Army in Artificial Intelligence

June 12, 1997

Certification Performance Standard

Certificants are not expected to be experts but must be above entry level in AI/Robotics. They must demonstrate competence in the important knowledge areas in AI/Robotics. A certificant who works in one area of AI/Robotics will be able to work in another area of AI/Robotics with minimal additional formal or on-the-job AI/Robotics training. Therefore, a manager can be confident that any AI/Robotics certificant hired is likely to be able to successfully perform the AI/Robotics aspects of the job.

Competence in core and supplemental knowledges must be demonstrated through a combination of the certificant's training, education, and experience. Strength in one area (e.g., experience) may compensate for weakness in another (e.g., education). The *typical* certificant will have an advanced degree in an AI/Robotics-related field and at least 6 months of relevant job experience. Thesis research in an area of AI/Robotics will count for the necessary experience; however, advanced degree holders who did not complete thesis work in AI/Robotics must demonstrate the equivalent application or experience. Certificants *without* advanced degrees can certify in the competency areas through a combination of training/education and hands-on experience in AI/Robotics.

Note: All core competencies can be satisfied through combinations of education or experience with the exception of Competency 5 (Methodologies for integrating AI with modeling, optimization, mathematical, statistical, or other computer programs). This competency can be satisfied *only* through experience and not through education.

Core Competencies (each certificant must fulfill all of these)

1. Expert/Knowledge-Based Systems
2. Object-Oriented/Symbolic/Logic Programming
3. Knowledge Representation
4. Basic Principles of AI
5. Methodologies for Integrating AI with Modeling, Optimization, Mathematical, Statistical, or Other Computer Programs
6. Knowledge Engineering

Supplemental Competencies (each certificant must fulfill any three of these)

7. Search Strategies
8. Heuristic Algorithms
9. Fuzzy Logic
10. Neural Networks
11. Application of AI Tools (e.g., preprocessors, shells)
12. Hybrid Systems
13. Path Planning
14. Blackboard Systems
15. Natural Language Processing
16. Genetic Algorithms
17. Case-Based Reasoning
18. Machine Learning
19. Speech Recognition/Synthesis
20. High-Level Computer Programming Languages
21. Conceptual Modeling of Problems and Solutions
22. Sensors
23. Sensor Fusion
24. Basic Principles of Robotics
25. Image Processing / Computer Vision
26. Control Theory
27. Robot Navigation

Descriptions of the Core Competencies

1 Expert/Knowledge-Based Systems

This competency covers the control architectures, data structures, and paradigms used in designing and building knowledge-based systems. It includes production systems, object-oriented programming, frames and default reasoning, logic-based approaches to knowledge representation, uncertainty formalisms, truth maintenance, and expert system software.

2 Object-Oriented/Symbolic/Logic Programming

This competency covers the fundamental principles of programming for Artificial Intelligence. It focuses on symbolic, logic, or object-oriented programming, and upon the application of development language and common AI techniques such as search or knowledge representation. It includes principles of analysis, design, development, and programming.

3 Knowledge Representation

This competency covers the control architectures, data structures, and paradigms used in designing and building AI systems, including production systems, object oriented programming, frames and default reasoning, logic-based approaches to knowledge representation, uncertainty formalisms, truth maintenance, and expert system software tools.

4 Basic Principles of AI

This competency covers the fundamentals of the core concepts of AI. Its primary focus is the integration between AI and other analytic problem solving techniques. It includes the history of AI; the applications of AI; and the fundamentals of knowledge representation, expert systems, and AI programming.

5 Methodologies for Integrating AI with Modeling, Optimization, Mathematical, Statistical, or Other Computer Programs

This competency covers hands-on practical experience in the application of AI techniques or research to problem solving. It involves defining the scope of a problem, selecting one or more appropriate AI techniques, and implementing the techniques to solve a problem.

6 Knowledge Engineering

The primary focus of this competency is on knowledge acquisition. This competency covers the acquisition of knowledge from a variety of sources, such as human experts and written documentation.

Descriptions of the Supplemental Competencies

7 Search Strategies

This competency addresses a fundamental area of problem solving: the state-space search. It covers traditional computational search strategies as well as AI-specific strategies such as depth-first, breadth-first, A*, and heuristic search.

8 Heuristic Algorithms

This competency covers the use of heuristics in problem solving. Heuristics are used when a problem's complexity or inherent ambiguities preclude exact (closed-form) solutions. It covers the discovery of "rules of thumb" and their application to problem solving.

9 Fuzzy Logic

This competency covers methods of modeling uncertainty utilizing fuzzy logic/set theory. It may include other non-traditional logic constructs.

10 Neural Networks

This competency covers concepts in neural networks and connectionist models. It includes parallel distributed processing, learning algorithms, and applications. Specific networks include Hopfield networks, bi-directional associative memories, perceptrons, feed-forward networks with back-propagation, and competitive learning networks (including self-organizing and Grossberg networks).

11 Application of AI Tools (e.g., preprocessors, shells)

This competency covers the control architectures, data structures, and paradigms used in designing and building knowledge-based systems. It includes, but is not limited to, production systems, object-oriented programming, frames and default reasoning, logic-based approaches to knowledge representation, uncertainty formalisms, truth maintenance, and expert system software tools. *The candidate must demonstrate the application of a commercial AI tool or shell. This application can include the development of an expert system or other shell in an AI programming language (see competency 2).*

12 Hybrid Systems

This competency covers the method of integrating two or more AI problem-solving techniques to solve a given problem. It includes, but is not limited to, the integration of an AI technique with a commercial AI shell.

13 Path Planning

This competency covers the fundamentals of state space search for the purpose of route selection or path planning. It can be used to simulate intelligent behavior in automated decision-making or used in robotic applications. Planning topics include obstacle avoidance, task planning, and navigation. Robotic path planning emphasizes vision (including binary image processing), robot vision, and knowledge-based vision systems.

14 Blackboard Systems

This competency covers a general problem-solving approach that requires the coordination of multiple processes or knowledge sources using a central global database for the communication of independent asynchronous knowledge sources or processes. Technical implementation includes, but is not limited to, object-oriented databases and object request brokers.

15 Natural Language Processing

This competency covers the concepts and methods for processing natural language by computer. It includes pattern matching, parsing, the role of the dictionary and lexical acquisition, semantic interpretation, anaphoric reference, plan recognition, discourse analysis, and text generation. Applications include natural language interfaces, text processing systems, advisory systems, and interaction with speech recognizers.

16 Genetic Algorithms

This competency covers genetic algorithms and other evolutionary based AI algorithms. It includes, but is not limited to, artificial life.

17 Case-Based Reasoning

This competency covers case-based reasoning as a type of analogical reasoning and as an alternative method for building systems. It includes case representation, indexing, retrieval, adaptation, and interpretive case-based reasoning. It also covers the cognitive model that underlies case-based reasoning and the model's implications for creativity, decision aids, and education.

18 Machine Learning

This competency covers inductive learning, explanation-based learning, and genetic algorithms. It includes neural networks, decision trees and graphs, delayed-reinforcement and temporal-difference learning, and computational learning theory. It focuses on the underlying concepts of machine learning and its role in AI.

19 Speech Recognition/Synthesis

This competency emphasizes processing of the human speech waveform, primarily using digital techniques. It covers the theory of speech production as it relates to signal models in time and frequency; it also covers the measurement of model parameters, short-time Fourier spectrum, and linear predictor coefficients. It may include speech coding, recognition and syntheses, and speaker recognition.

20 High-Level Computer Programming Languages

This competency covers traditional computer programming. It includes analysis, design, development, and programming. The focus is on application development.

21 Conceptual Modeling of Problems and Solutions

The focus of this competency is on problem definition and structuring. It involves the application of knowledge representation schemes and search methods to describe a problem space prior to the selection and application of a problem-solving approach.

22 Sensors

This competency covers the fundamentals of sensing, with an emphasis on vision. It includes binary image processing, robot vision, and knowledge-based vision systems.

23 Sensor Fusion

This competency covers the combining of input from disparate sensors for the purpose of decision-making. It includes, but is not limited to, the application of measures of uncertainty/belief. In robotics applications, it includes the integration of sensor inputs to establish situation awareness.

24 Basic Principles of Robotics

This competency covers the fundamentals of robot technology with an emphasis on programming concepts. It includes robot control, robot hardware, the mathematics of robot control (local and global coordinate systems and transformations between them), and robot programming languages. Planning includes obstacle avoidance, task planning, and navigation. Sensing emphasizes vision, including binary image processing, robot vision, and knowledge-based vision systems.

25 Image Processing / Computer Vision

This competency covers the basic techniques of analysis and manipulation of pictorial data by computer. It includes image input/output devices, image processing software, enhancement, segmentation, property measurement, and Fourier analysis.

26 Control Theory

This competency covers modeling, analysis, and the fundamentals of design for feedback control systems. It includes state equations, transfer function representations, stability, performance measures, control systems (hydraulic, electrical, mechanical, and pneumatic), open and closed loops, steady state and transient operation, and linear and non-linear systems.

27 Robot Navigation

This competency covers the fundamentals of robot technology. It emphasizes sensing and planning. Planning topics include obstacle avoidance, task planning, and navigation. Sensing topics include vision (including binary image processing), robot vision, and knowledge-based systems.

General Statement of Certification Requirements for Course Work, Experience, and Combinations of Experience and Course Work

Candidates must demonstrate sufficient mastery in all six core competencies and three supplemental competencies. This may be done for each applicable competency area via related experience, relevant course work, or combinations of both. This section describes how a candidate can meet the requirements for a competency. The *typical* certificant will have an advanced degree in an AI/Robotics-related field and at least 6 months of relevant job experience. Thesis research in an area of AI/Robotics will count for the necessary experience; however, advanced degree holders who did not complete thesis work in AI/Robotics must demonstrate the equivalent application or experience. Certificants *without* advanced degrees can certify in the competency areas through a combination of training/education and hands-on experience in AI/Robotics.

Course Work

A list of courses that may be used to fulfill the certification requirements for each competency follows. The list of courses is not meant to be exhaustive. If a candidate lists a course that is *not* on this list, the course information should be compared with the courses that *are* on the list to help determine whether the course meets the requirements for certification. The list of courses includes a *prototype* course for each competency. A prototype course for a competency is the course that best matches the requirements for that competency. A *Prototype Courses Linked to Competencies* table is also provided to graphically provide some of the information contained in the list of courses.

For Competency 5 (Methodologies for integrating AI with modeling, optimization, mathematical, statistical, or other computer programs), courses cannot be used for either full or partial credit; this competency can be satisfied only through experience.

The candidate must demonstrate the application of AI tools to solve a problem. The application must be beyond the scope of a mere course project. AI-related thesis research or six months of applied experience is the minimum requirement.

A course may partially or completely fulfill the requirements for a competency. A course that partially satisfies a competency may be combined with experience to fulfill the requirements for a competency (as described below), but it cannot be combined with other courses.

Experience

The certification review panel will look for active involvement in the design or development of AI systems *or* active involvement in the verification, validation, testing, or evaluation of AI systems. The experiences must equip a person with sufficient knowledge to make appropriate choices when solving a problem. Six months of relevant experience, where at least 50% of the candidate's time was devoted to relevant AI/Robotics activities, will typically be required to receive full credit for a competency.

Experience + Course Work Combinations

The Board will look for active involvement in AI projects in conjunction with related course work. The completion of a short course *combined with* active involvement in parts of related projects or technical oversight (of design, development, or testing) may be used to fulfill the requirements for a competency. Typically, courses must be at least two days in duration (or 2 credit hours for courses that last a semester) and relevant experience must be at least 3 months, where at least 50% of the candidate's time was devoted to relevant AI/Robotics activities, to receive full credit for a competency.

Kinds of Experiences or Combinations that are *Enough* for most AI/Robotics Competencies

- participated in a co-op program
- was a visiting scholar
- performed job-related or graduate research
- was actively involved in work on a relevant *component* of a project *and* took a short course
- provided technical oversight of design, development, or testing to a project/program *and* took a short course
- active participation in selection of techniques
- active design of solutions and approaches

Kinds of Experiences or Combinations that are *Not Enough* for most AI/Robotics Competencies

- oversight of projects (i.e., program management)
- attended a one-day class or workshop
- attended a conference tutorial (While we encourage professionals to participate in conference tutorials in order to remain current, they do not satisfy the requirements for certification.)
- membership in an AI/Robotics-related professional organization
- developed solutions using traditional computational/mathematical/optimization techniques (especially using a single COTS shell)

Detailed Examples

The examples above, of kinds of experiences and combinations of experience and course work that are either sufficient or insufficient for certification, are general in nature. More detailed examples, for each core competency, are shown later.

Competencies Linked to Prototype Courses

Core Competencies

KSA ID	KSA Description	11	46	55	67	87	116	134	137	150	167	212	216	232	235	237	238	242	249	296	347
1	expert/knowledge-based systems		■			■						■	P								
2	object-oriented/symbolic/logic programming						■		■	■		P	P					■	■		
3	knowledge representation		■			■						■	■								
4	the basic principles of AI					P						■	■								
5	methodologies for integrating AI with modeling, optimization, mathematical, statistical, or other computer programs																				
6	knowledge engineering		P			■							P								

Supplemental Competencies

KSA ID	KSA Description	11	46	55	67	87	116	134	137	150	167	212	216	232	235	237	238	242	249	296	347
7	search strategies												■								
8	heuristic algorithms												P								
9	fuzzy logic			■															P		
10	neural networks				■							■									
11	the application of AI tools (e.g., preprocessors, shells)		■			■						■									
12	hybrid systems											P									
13	path planning	■																			
14	blackboard systems																				
15	natural language processing												P		■						
16	genetic algorithms							■												P	
17	case-based reasoning																			P	■
18	machine learning																			■	
19	speech recognition/synthesis													■							
20	high-level computer programming languages						■		■	■								■			
21	conceptual modeling of problems and solutions		P			■						■	P								
22	sensors	P																			
23	sensor fusion	P																			
24	basic principles of robotics	■																			
25	image processing / computer vision															■	■				
26	control theory	P									■										
27	robot navigation	■																			

■ = Full Credit P = Partial Credit

Prototype-Course to Competency Mapping

ID **Prototype-Course Title**

11 Robotics

Additional Courses:

11 Robotics
29 Introduction to Robotics

189 Robotics
246 Advanced Topics in AI: Robotics
297 Robot Navigation

Description of Prototype Course:

The course introduces the fundamentals of robot technology with an emphasis on programming concepts. Topics covered in robot control are robot hardware, the mathematics of robot control (local and global coordinate systems and transformations between them), and robot programming languages. Planning topics include obstacle avoidance, task planning, and navigation. Sensing emphasizes vision, including binary image processing, robot vision, and knowledge-based vision systems. Programming assignments and a laboratory are included.

Competency Number	Competency Title
22	Sensors
23	Sensor Fusion
24	Basic Principles of Robotics
26	Control Theory
27	Robot Navigation
13	Path Planning

ID **Prototype-Course Title**

46 Expert Systems

Additional Courses:

15 Knowledge-based Systems and AI
45 Introduction to Experts Systems

46 Expert Systems
83 Expert Systems in Ind. Engineering
118 Expert Systems: Practical Applications of AI
132 Knowledge-based Systems
151 Expert Systems
181 Knowledgebases
243 Advanced Topics in AI: Expert Systems

Description of Prototype Course:

This course explores the control architectures, data structures, and paradigms used in designing and building knowledge-based systems. Topics include production systems, object-oriented programming, frames and default reasoning, logic-based approaches to knowledge representation, uncertainty formalisms, truth maintenance, and expert system software tools. A number of case studies from the expert systems literature are also considered. The class has a laboratory in which expert system shells are used to develop concepts discussed in the lectures.

Competency Number	Competency Title
1	Expert/Knowledge-Based Systems
3	Knowledge Representation
6	Knowledge Engineering
21	Conceptual Modeling of Problems and Solutions
11	Application of AI Tools (e.g. preprocessors, shells)

ID	Prototype-Course Title
55	Fuzzy Logic

Additional Courses:

55 Logics for Computer Science

Description of Prototype Course:

This course introduces the student to formal systems, their syntax, semantics, manipulation, and interpretation. Propositional and predicate logics are introduced as mathematical systems and as formal models of (parts of) human reasoning. Applications emphasize the logical investigation of the properties of various data structures. Several alternative logics are presented, such as modal, multi-valued, fuzzy, temporal, intuitionistic, and inductive. These are discussed as potential tools in knowledge representation and cognitive science.

Competency Number	Competency Title
9	Fuzzy Logic

ID	Prototype-Course Title
67	Neural Networks

Additional Courses:

67 Neural Networks
128 Neural Network Short Course

135 Neural Computing
141 Neural Networks
160 Applied Neural Network computing
161 Artificial Neural Systems and Neural Computing
162 Applying Neural Computing
163 Advanced Neural Computing
164 Empirical Modeling Using Neural Networks
204 Neural net and Parallel Systems
261 Applying Neural Networks

Description of Prototype Course:

This course provides an introduction to concepts in neural networks and connectionist models. Topics include parallel distributed processing, learning algorithms and applications. Specific networks discussed include Hopfield networks, bidirectional associative memories, perceptrons, feedforward networks with back propagation, and competitive learning networks, including self-organizing and Grossberg networks

Competency Number	Competency Title
10	Neural Networks

ID	Prototype-Course Title
87	Building Expert Systems

Additional Courses:

87 Building Expert Systems

Description of Prototype Course:

Building Expert Systems is an introductory through-intermediate level guide to knowledge engineering and expert system development. Students are guided via lecture and computer lab through the construction of a small but fully functioning expert system. The course contains an historical and theoretical overview of the discipline of Artificial Intelligence, a comprehensive review of successful expert systems (e.g., corporate, academic, and military implementations), and reviews those successful strategies used in AI development. The primary focus of this course is on knowledge elicitation and representation. The purpose of the course is to provide specialized training in the development of Expert/Knowledge-based Systems to Army Officers in the Functional Areas 49 and 53 and DA Civilians working with AI.

Competency Number	Competency Title
1	Expert/Knowledge-Based Systems
3	Knowledge Representation
4	Basic Principles of AI
6	Knowledge Engineering
21	Conceptual Modeling of Problems and Solutions
11	Application of AI Tools (e.g. preprocessors, shells)

ID	Prototype-Course Title
116	Programming in Prolog

Additional Courses:

116 Programming in Prolog
244 Advanced Topics in AI: Logic Programming

Description of Prototype Course:

This course provides an introduction to Prolog, the foundations of logic programming, and current research on applications of logic within artificial intelligence. The course proceeds on two parallel tracks, with each class session divided about equally between the two. One track focuses on Prolog programming. It begins with a thorough treatment of Prolog, and then considers applications of Prolog to natural language processing and other areas. The other track focuses on theoretical issues. It begins with a review of firstorder logic and the resolution principle and then considers theoretical aspects of logic programming, including the semantics of logic programs and alternative proof procedures. Finally, it examines some of the alternatives to first-order logic that AI researchers have considered recently to overcome inadequacies of traditional logical method) for building intelligent systems. These alternatives include modal logics for representing and reasoning about knowledge and belief, and nonmonotonic and default logics. Assignments include problem sets and a number of Prolog programs.

Competency Number	Competency Title
2	Object-oriented/Symbolic/Logic Programming
20	High-Level Computer Programming Languages

ID	Prototype-Course Title
119	AI Research/Experience

Description of Prototype Course:

Application development experience, thesis research or

Competency Number	Competency Title
5	Methodologies for Integrating AI with Modeling, Optimization, Mathematical, Statistical, or Other Computer Programs
21	Conceptual Modeling of Problems and Solutions
11	Application of AI Tools (e.g. preprocessors, shells)

ID	Prototype-Course Title
134	Genetic Algorithms

Additional Courses:

134 Genetic Algorithms

Description of Prototype Course:

This course will discuss Genetic Algorithms and other evolutionary based AI algorithms, including a small component on Artificial Life. GAs are easy to understand, easy to program, and very powerful tools. They are being used to do all kinds of things these days, including machine learning, gas pipeline routing, airplane wing design, function optimization, scheduling (including scheduling task/processor assignments in parallel systems), resource allocation, and other types of hard problems for which it is not possible to directly compute the best answer.

Competency Number	Competency Title
16	Genetic Algorithms

ID	Prototype-Course Title
137	Object-oriented Programming

Additional Courses:

137 Object-oriented Programming
157 Object Oriented Design and Analysis
179 C++ Object Oriented Programming
203 Object Oriented Programming
211 C++ Programming

Description of Prototype Course:

Principles of object-oriented analysis and design, development, and programming Includes relation Dip. Between object-oriented design concepts and software engineering principle, techniques of object-oriented design and programming and appoint object-oriented technique.

Competency Number	Competency Title
2	Object-oriented/Symbolic/Logic Programming
20	High-Level Computer Programming Languages

ID	Prototype-Course Title
150	LISP Programming

Description of Prototype Course:

Introduction to computer programming in Common LISP, with a focus on preparing the student for using Common LISP and AI programming techniques to solve problems in

Additional Courses:

79 Porting LISP Applications to Stock Hardware
80 Intro to LISP Programming
150 LISP Programming
152 Introduction to Common LISP

Competency Number	Competency Title
2	Object-oriented/Symbolic/Logic Programming
20	High-Level Computer Programming Languages

ID	Prototype-Course Title
167	Control theory

Description of Prototype Course:

Modeling, analysis and an introduction to design for feedback control systems. Topics include state equation, and transfer function representations, stability, performance measures, hydraulic, electrical, mechanical and pneumatic control systems, open and closed loops, steady state and transient operation and linear and non-linear systems.

Additional Courses:

14 Theory and Applications of Fuzzy Control
33 Advanced Systems Control
34 Automatic Controls
158 Adaptive Control
159 Hybrid Controls
167 Control theory
221 Feedback Controls

Competency Number	Competency Title
26	Control Theory

ID	Prototype-Course Title
212	ITOR

Additional Courses:

212 ITOR

Description of Prototype Course:

The ITOR course provides the student with an introduction to the world of Artificial Intelligence (AI). The fields in AI that the student explores includes Neural Networks, Expert Systems and Object-Oriented Programming. The key focus of the course is to provide insight into the integration between this new knowledge and other analytic problems solving techniques. The course contains a touch of theory coupled with ample hands-on application. This combination provides students with an ability to solve reasonable size problems in each field before graduation. The course goals are to:

1. Obtain a working knowledge AI and expert systems concepts.
2. Identify appropriate applications of AI Technology to real world problems.
3. Create AI applications using neural networks, rule based expert systems and object-oriented programming.
4. Experience the development processes involved with EXSYS, SNNAP, and Kappa PC.
5. Create a working prototype of a project from the

Competency Number	Competency Title
1	Expert/Knowledge-Based Systems
2	Object-oriented/Symbolic/Logic Programming
3	Knowledge Representation
4	Basic Principles of AI
21	Conceptual Modeling of Problems and Solutions
10	Neural Networks
11	Application of AI Tools (e.g. preprocessors, shells)
12	Hybrid Systems

ID	Prototype-Course Title
216	Artificial Intelligence

Additional Courses:

20 Introduction to AI
35 Introduction to AI

89 Advanced AI
109 Advanced AI
117 Problem-solving Methods in AI

131 Introduction to AI
216 Artificial Intelligence

Description of Prototype Course:

The course addresses two major areas: representation and reasoning. Topics focusing on representation include symbolic, production rule, frame, object, and semantic net representational schemes. Topics focusing on reasoning may include weak methods (path finding, constraint propagation, games, general heuristic search, decomposition, general problem solver, generate and test, hill climbing), deduction, explanation, uncertainty, non-monotonic reasoning, temporal reasoning, model-based reasoning, and planning. Applications may include production rule systems, natural language examples, learning, and planning. Common LISP is introduced as a tool for expressing symbolic knowledge.

Competency Number	Competency Title
1	Expert/Knowledge-Based Systems
2	Object-oriented/Symbolic/Logic Programming
3	Knowledge Representation
4	Basic Principles of AI
6	Knowledge Engineering
7	Search Strategies
20	High-Level Computer Programming Languages
21	Conceptual Modeling of Problems and Solutions
8	Heuristic Algorithms
15	Natural Language Processing

ID	Prototype-Course Title
232	Speech Processing

Additional Courses:

232 Speech Processing

Description of Prototype Course:

The course emphasizes processing of the human speech waveform, primarily using digital techniques. Theory of speech production as related to signal models in time and frequency domains is covered, as well as the measurement of model parameters, short-time Fourier spectrum, and linear predictor coefficients. Speech coding, recognition and synthesis, and speaker recognition are also included. Some consideration is given to speech processing hardware. Software projects are required.

Competency Number	Competency Title
19	Speech Recognition/Synthesis

ID **Prototype-Course Title**

235 Natural Language Processing

Additional Courses:

235 Natural Language Processing

Description of Prototype Course:

Natural Language Processing This covers the concepts and methods for processing natural language by computer. Topics include pattern matching, parsing, the role of the dictionary and lexical acquisition, semantic interpretation, anaphoric reference, plan recognition, discourse analysis, and text generation. Applications are drawn from natural language interfaces, text processing systems, advisory systems, and interaction with speech recognizers. A "hands on" natural language processing development tool is used.

Competency Number	Competency Title
15	Natural Language Processing

ID **Prototype-Course Title**

237 Image Processing

Additional Courses:

142 Statistical Pattern Recognition
195 Image Processing/Robot Vision
237 Image Processing

Description of Prototype Course:

An introduction to basic techniques of analysis and manipulation of pictorial data by computer. Image input/output devices, image processing software, enhancement, segmentation, property measurement, Fourier analysis. Computer encoding, processing, and analysis of

Competency Number	Competency Title
25	Image Processing / Computer Vision

ID **Prototype-Course Title**

238 Computer Vision

Additional Courses:

12 Computer Vision and Image Processing
170 Machine vision
174 Statistical Techniques in computer Vision
238 Computer Vision

Description of Prototype Course:

Image processing: edge detection, segmentation, local features, shape and region description in 2D and 3D. Insights from human vision. Representation for vision: object models, synthetic images, matching, gaps, algorithms. Inference, production system, syntactic networks. Planning, spatial reasoning for robot vision.

Competency Number	Competency Title
25	Image Processing / Computer Vision

ID	Prototype-Course Title
242	Artificial Intelligence Programming

Additional Courses:

1 Symbolic and Logic Programming
242 Artificial Intelligence Programming

Description of Prototype Course:

This course focuses on implementing AI techniques in Common LISP. As such, it has two main themes: the algorithms needed to implement AI techniques efficiently, and the LISP techniques needed to put the algorithms into practice. The course consists primarily of programming projects. AI Programming techniques may include a deeper look at heuristic search and efficiency issues of search programs, chart parsing for efficiently parsing natural language, object-oriented and frame-based representations, rule-based expert systems, etc. LISP issues include programming methods as well as LISP functions and data structures. Programming methods may include symbolic programming, using lexical closures, memorization, and a review of recursive techniques. LISP functions and data structures may include the Common LISP Object System (CLOS), hash tables, functions as first-class objects, macros, structures, and lists.

Competency Number	Competency Title
2	Object-oriented/Symbolic/Logic Programming
20	High-Level Computer Programming Languages

ID	Prototype-Course Title
249	Logic, Language and Machines

Additional Courses:

249 Logic, Language and Machines

Description of Prototype Course:

The overall objective of this course is to introduce the student to formal systems: their syntax, semantics, manipulation, and interpretation. Computer programs are themselves formal systems, and the subject matter underlies work in the areas of correctness, consistency, and completeness proofs for programs. Topics include an introduction to symbolic logic, presented as an attempt to formally model human reasoning; and inductive logic in the context of modeling the reasoning involved in drawing conclusions from limited, possibly faulty information (this material is of particular interest for its potential in artificial intelligence research and development in the area of cognitive modeling). Finally, a survey is presented of other logical systems of interest in the areas of knowledge representation and reasoning under certainty: topics discussed will include modal, fuzzy, and probabilistic logics.

Competency Number	Competency Title
2	Object-oriented/Symbolic/Logic Programming
9	Fuzzy Logic

ID	Prototype-Course Title
296	Machine Learning

Additional Courses:

296 Machine Learning

Description of Prototype Course:

Survey of major research areas: inductive learning, explanation-based learning, and genetic algorithms. Topics: neural networks, decision trees and graphs, delayed-reinforcement and temporal-difference learning, and computational learning theory. Focuses on the underlying concepts and the role of machine learning in AI. Representative systems described. Prerequisites: 221 or consent of instructor, and ability to write computer programs in one or more commonly used languages.

Competency Number	Competency Title
16	Genetic Algorithms
17	Case-Based Reasoning
18	Machine Learning

ID	Prototype-Course Title
347	Case-Based Reasoning

Additional Courses:

298 Case-based reasoning

Description of Prototype Course:

Case-based reasoning is a kind of analogical reasoning and an alternative method for building expert systems. Topics include case representation, indexing, and retrieval, adaptation, interpretive case-based reasoning, the cognitive model case-based reasoning implies, and its implications for creativity, decision aiding, and education.

Competency Number	Competency Title
17	Case-Based Reasoning

Examples of Experience or the Combination of Experience + Course Work for Each Core Competency

For each core competency below, two examples of experience are shown. The *Enough* experience is good enough for certification in that competency. That is, no courses or other experiences are required. The *Not Enough* experience is insufficient for certification.

Competency	Example of Enough Experience	Example of *Not* Enough Experience
1. Expert/knowledge-based systems	Provided technical oversight for an expert/knowledge-based system project plus completion of a 3-day training class; was actively involved in the design, development, or testing of an expert/knowledge-based system	Provided program oversight for an expert/knowledge-based system project (little depth or breadth of experience) plus attendance at a 1-day workshop or conference tutorial.
2. Principles of object-oriented/symbolic/logic programming	Selected the appropriate programming language and designed or implemented an AI system or subsystem in that language.	Developed test case object-oriented program from a textbook.
3. Knowledge representation	Organized data to perform intelligent operations (i.e., organized data into a form that is ideal for reasoning about the data); selected and applied the appropriate knowledge representation scheme (i.e., set of syntactic and semantic conventions) to solve a problem.	Built a relational database program; used traditional data structures.
4. Basic principles of AI	Completed a 2-day short course *and* applied the appropriate AI principles and techniques to solve a problem.	Completed a short course; applied a specific AI technique to solve a textbook sample problem.

Competency	Example of Enough Experience	Example of *Not* Enough Experience
5. Methodologies for integrating AI with modeling, optimization, mathematical, statistical, or other computer programs.	Derived the definition and solution of a multi-domain problem; participated in an interdisciplinary team to provide AI support to a project; developed an AI module as a component in a larger system; applied a methodology for integrating AI with modeling, optimization, mathematical, statistical, or other computer programs.	Developed a stand-alone AI system.
6. Knowledge engineering	Extracted knowledge from expert sources (e.g., humans, written documentation) with the intent of populating a knowledge representation framework/structure that is well-suited to solving the problem.	Uploaded data into a database.